ELEMENTS OF GEOLOGY:

INCLUDING

FOSSIL BOTANY AND PALÆONTOLOGY.

A POPULAR TREATISE

ON THE MOST INTERESTING PARTS OF THE SCIENCE.

DESIGNED FOR THE USE OF SCHOOLS AND GENERAL READERS.

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AUTHOR OF NATURAL PHILOSOPHY, INTRODUCTION TO BOTANY, ELEMENTS OF CHEMISTRY, ELEMENTS OF MINERALOGY, A TREATISE ON PHYSICAL GEOGRAPHY, OUTLINES OF PHYSIOLOGY, AND NATURAL HISTORY OF BIRDS AND BEASTS.

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PREFACE.

WHEN comparing the last stereotype impression of my "OUTLINES OF GEOLOGY," published in 1834, with the most recent geological works of the present day, with the intention of rëforming it into a new edition, I have found that such had been the progress of the science during the last few years, that a considerable portion of the work would require an entire change.

Instead, therefore, of presenting my friends and the public, with a *new edition*, I herewith offer them a *new book;* and which, I cannot but think, contains much more interesting and important matter, than the old one did, even when it was new.

The subjects of FOSSIL BOTANY and ANIMAL REMAINS, have received particular attention; these being not only the most popular and instructive branches of Geology, but those on which naturalists, both at home and abroad, have lately bestowed the most laborious and profound investigations.

Some of the old Lignographs, with their descriptions, on points where no improvements had been made, and also some of my speculations on the "MOSAIC SYSTEM OF BOTANY," and on the "DAYS OF CREATION," have been retained. In other respects, the work is made of new matter, and has a new name.

With respect to the illustrations, the engravings were executed by Mr. Seth H. Clark, and stereotyped by Mr. R. H. Hobbs, both of this city; and I have much pleasure in believing that, in works of this description, our country can show no better specimens of either art.

Hartford. (*Conn.*) *March*, 1847.

AUTHORITIES.

The following is a list of books which have been consulted, and most of them quoted in the progress of this work:

De la Beche's Geological Manual.
Ures' System of Geology, London.
Bakewell's Geology.
Macculloch's Geology, 2 vols., London.
Penn's Comparative Estimate, 2 vols., London.
Parkinson's Organic Remains, London.
Buckland's Bridgewater Treatise.
Buckland's Reliquiæ Diluvianæ.
Mantell's Wonders of Geology, 2 vols., London.
Mantell's Medals of Creation, 2 vols., London.
Lyell's Principles of Geology, 3 vols.
Lyell's Elements of Geology, 2 vols.
Lyell's Travels in North America, 2 vols.
Cuvier's Animal Kingdom, 5 vols.
Cuvier's Ossemes Fossiles.
Cuvier's Revolutions of the Glòbe.
Hitchcock's Report on the Geology of Massachusetts.
Brande's Outlines of Geology.
Mawes' Conchology, London.
Richardson's Geology, London.
United States Exploring Expedition, 5 vols.
Conybeare and Phillips' Geology, London.
Various Geological Reports.
Silliman's Journal.
Edinburgh Philosophical Journal.

EXPLANATIONS

M. C.	means	Medals of Creation.
Wond.	"	Wonders of Geology.
Bd.	"	Buckland's Bridgewater Treatise.
Rd.	"	Richardson's Geology.
Ly. P.	"	Lyell's Principles of Geology.
Ly. E.	"	Lyell's Elements of Geology.
Lign.	"	Lignograph, wood cut.

Dr. MANTELL's Works contain some of the most beautiful geological engravings, extant; and to these I am chiefly indebted for the ornamental part of my book.

LIST OF LIGNOGRAPHS.

ELEMENTS OF GEOLOGY.

CHAPTER I.

PRELIMINARY EXPLANATIONS.

1. *Definition.* The term GEOLOGY is derived from Greek; *ge*, the "earth," and *logos*, "reason," or "discourse," and therefore signifies the doctrine or science of the earth. It is the physical history of the globe, and has for its object, the investigation of the causes which have produced the phenomena exhibited both by the external and interior portions of the planet on which we live.

2. *More extensive view of Geology.*—As the student proceeds in the study of this science, he will find that it includes within its inquiries nearly every natural subject which the mind of man has ever investigated. In close connection with it, and indeed forming portions of its legitimate inquiries, are the sciences of Mineralogy, Botany, Conchology, and Zoology.

3. Zoology being the science of animals generally, includes the different departments of Ichthyology, or the study of fishes; Ornithology, that of birds; Entomology, that of insects; Malacology, that of soft animals, as the clam and oyster, and Mammalogy, that of milk-giving animals.

4. Besides the above named sciences, Geology has given rise to a new science called Palæontology, or the study of the fossil, organic remains of animals.

5. Now, lest the student should be discouraged at the onset with the idea that an intimate knowledge of all these sciences is necessary in order to proceed with that of Geology, we deem it proper to state here that so much of each of these subjects as is required for his present

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What is the meaning of the term Geology? What does the science of Geology include? What are the sciences most nearly connected with it? What does the science of Zoology include? What is Palæontology?

purpose will be so explained as to be readily understood. It must not, however, be concealed that the student who begins the study of Geology with a good knowledge of Botany, Mineralogy, Conchology, and indeed of natural history generally, has a great advantage over him who knows little or nothing of these subjects.

6. The objects embraced by Palæontology, as the petrified or fossil remains of fish, animals, and shells, have been appropriately and eloquently called the MEDALS OF CREATION; for, says Mr. Mantell, "as an accomplished numismatist, (or reader of coins,) even when the inscription of an ancient and unknown coin is illegible, can, from the half obliterated characters, and from the style of art, determine with precision the people by whom, and the period when it was struck; in like manner the geologist can decipher these natural memorials, interpret the hieroglyphics with which they are inscribed, and from apparently the most insignificant relics trace the history of beings of whom no other records are extant, and restore anew those forms of organization which lived and died, and whose races were swept from the face of the earth, ere man and the creatures which are his contemporaries became its denizens." M. C. p. 23.

ARRANGEMENT OF STRATA AND THEIR CONTENTS.

7. The solid materials composing the earth, so far as man has observed, consist of *Minerals* and *Fossils*.

The depth, or perpendicular distance to which geologists have been able to extend their observations is estimated at about fifteen miles. This distance includes the highest mountains, and the deepest valleys.

MINERALS.

8. Minerals are inorganic substances formed by natural causes, some by heat, and some by water. They form the great body of which the earth is composed, as *granite*, *gneiss*, *trap*, *limestone*, and *sandstone*. The great ranges of mountains in every part of the globe, are chiefly composed of these materials. It will be shown hereafter which class owes their origin to fire, and which to water.

What sciences are considered important in the study of Geology? What are the objects embraced by Palæontology? Why are fossils called the Medals of Creation? What are the solid materials of the earth? What ***are minerals? How have minerals been formed?***

FOSSILS.

9. Fossils are remains of animals and vegetables, which at unknown periods of time have been entombed in the strata of the earth by natural causes. Most of these remains though they may still maintain their original shapes, are found to have lost all their animal or vegetable matter, being petrified, or *turned into stone*, as the common expression is. This idea is, however, far from conveying the truth, for although the fossil may, and does often retain the exact form of the animal or vegetable body from which it was moulded, still there has been no transformation from one to the other, but only a deposition of the stony particles, as those of the organic matter decayed, and evaporated, or were washed away. Thus the stone imitates the organic relic.

10. In many instances such have been the immense depositions of animal remains, particularly of shells, and the silicious cases of animalcules called *infusoria*, that entire strata, of great thickness and extent, appear to have been formed of these materials, to the exclusion of all others.

11. As examples of the great extent to which the solid materials of the earth are owing to animal origin, we transcribe the following from Mr. Mantell's *Medals of Creation.*

12. These formations include hundreds of miles in extent, and are, some of them, several hundred feet in thickness; and when we consider the comparatively small portions of the earth which have been examined for such purposes, and that none of them are on this side of the Atlantic, we may, perhaps, form some idea of the great extent to which the solid portions of the globe are owing to organic materials.

13. *Rocks composed chiefly of animal remains.*

STRATA.	PREVAILING FOSSILS.	FORMATIONS.
Trilobite schist.	Trilobites and shells.	Silurian
Dudley limestone.	Corals, shells, trilobites, crinoidea.	system.
Shelly limestone.	Productæ, spiriferæ.	"
Mountain limestone.	Corals and shells.	Corboni-
Encrinital marble.	Lily-shaped animals and shells.	ferous
Mussel-band.	Fresh water mussels.	system.
Ironstone nodules.	Trilobites, insects, and shells.	"

What are fossils? How are petrifactions formed? What is said of the vast amount of animal depositions? What is said of the extent of the formations *composed* of animal remains?

STRATA.	PREVAILING FOSSILS.	FORMATIONS.
Lias-shales and clays.	Pentacrinites, reptiles, and fishes.	Lias.
Limestone.	Terebratulæ and other shells.	"
Lias conglomerates.	Fishes, shells, corals.	"
Gryphite limestone.	Shells, principally gryphites.	"
Limestone.	Terebratulæ and other shells.	Inferior
Stonesfield slate.	Shells, reptiles, fishes, insects.	Oolite.
Pappenheim schist.	Crustacea, reptiles, fishes, insects.	Oolite.
Bath-stone,	Shells, corals, crinoidea, reptiles.	"
Limestone.	Cephalopoda, principally ammonites.	"
Coral-rag.	Corals, shells, echini, ammonites.	"
Bradford limestone.	Crinoidea, shells, corals, cephalopoda.	"
Portland oolite.	Ammonites, trigoniæ, and other shells.	"
Purbeck and Sussex marble.	Fresh-water shells, reptiles, fishes.	Wealden.
Wealden limestone.	Cyclades, crustacea, reptiles, fishes.	"
Tilgate grit.	Reptiles, fishes, shells.	"
Farringdon gravel.	Sponges, corals, echini, shells.	Shanklin
Jasper and chert.	Shells, sponges, animalcules.	sand.
Greensand.	Fibrous zoophytes.	"
Chalk.	Corals, infusoria, echini, shells.	Chalk.
Maestricht limestone.	Corals, ammonites, belemnites, reptiles.	"
Hippurite limestone.	Shells, principal'y hippurites.	"
Hard chalk,	Echini and belemnites.	"
Flints.	Infusoria, echini, corals, shells, &c.	"
Limestone.	Fresh-water shells.	Tertiary.
Nummulite rock.	Nummulites.	"
Septaria.	Nautili, turritellæ, shells.	"
Calcaire grossier.	Shells and corals.	"
Gypseous limestone.	Mammalia, birds, reptiles, fishes.	"
Siliceous limestone.	Shells,	"
Lacustrine marls.	Cyprides, fresh-water shells.	"
Monte Bolca sandstone.	Fishes in abundance.	"
Bone-breccia.	Mammalia and land-shells.	"
Sub-Himalaya limestone.	Elephant, Mastodon, reptiles.	"
Tripoli.	Infusoria, nearly entire.	"
Richmond marl.	Animalcules and infusoria.	"
Semiopal.	Infusoria.	"
Mountain meal.	Infusoria.	"
Guadaloupe limestone.	Human bones, shells, and corals.	Human
Bermuda limestone.	Corals, shells, serpulæ.	epoch.
Bermuda chalk.	Comminuted corals, shells.	"
Bog-iron ochre.	Infusoria. M. C. p. 21.	"

VEGETABLE REMAINS.

14. The solid parts of the earth which have been derived from vegetables, though probably not so great as those above described, are still of vast extent in different parts of the world. These formations, known at the present

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What is said of the existence of coal, where climate renders it necessary for the comfort of man?

day under the name of *coal fields*, exist, probably, in most parts of the world where the climate renders large quantities of fuel necessary for the comfort of man; a signal interposition of the Creator for his benefit, and clearly proving that it emanated from design, since coal has rarely, if ever, been discovered in any quantities in hot climates.

VEGETABLE ORIGIN OF COAL.

15. Among the early geologists, the origin of coal was for a long time a matter of dispute; but at the present day it is universally admitted that all its varieties are of vegetable origin.

16. *Proofs of the origin of Coal.*—The experiments of Prof. Göppert, of Breslau, on the transformation of vegetables into coal, and which were afterwards followed in England, appear to have left no doubt on this subject in the mind of any philosopher; though perhaps they only served to confirm opinions formed on less certain grounds.

17. This philosopher endeavored to imitate the agency of nature in producing the results in question, and he did so with perfect success. Having observed that the leaf, (that of the fern) in iron-stone nodules, might occasionally be separated, in the form of a carbonaceous film, he placed such leaves in clay, dried them in the shade, and then exposing the clay to a red heat, he thus obtained striking resemblances to the fossil plants. According to the degree of heat, the plant was found to have become either brown, shining black, or to be entirely lost, the impression only remaining; but, in the latter case, the surrounding clay was stained black, thus indicating that the color of the coal-shales is derived from the carbon of the plants which they include, or once included.

PROCESS OF NATURE IN THE FORMATION OF COAL.

18. *It might be supposed from the results of the above experiments*, that the action of volcanic heat on vegetables was required to produce coal; this supposition is, however, by no means entertained: the application of artificial heat being the only means by which the long processes of

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What has been the origin of mineral coal? What were Göppert's experiments to show the vegetable origin of coal?

nature, consisting of fermentation and pressure, could be imitated.

19. *Changes produced on hay and other vegetables.*—If hay be stacked in a moist condition, and closely packed, it is well known that fermentation will be the result, especially, during the hot season, and that the heat produced is sometimes so great as to produce spontaneous combustion, by which the mass is consumed. But if care be taken to confine the mass from contact of the air, and thus prevent ignition, the hay will be found to have acquired a dark brown color, a glazed or oily appearance, and a bituminous smell, resembling that of coal. The same result will be produced if flax, hemp, ferns, the twigs of trees or other small vegetables, capable of being pressed into a close mass, be treated in the same manner.

20. Now this is considered an illustration, on a small scale, of what was once performed by natural means, to such a vast extent as to produce large coal fields, by throwing into masses whole forests, instead of a few pounds of hay, and then subjecting such accumulations to the pressure, perhaps, of hundreds of feet of incumbent earth.

21. *Structure of bituminous coal.*—Although the vegetable origin of all coal will not admit of question, yet, says Mr. Mantell, evidence of the original structure is not always attainable. The most perfect bituminous coal has undergone (apparently) a complete liquefaction, and if any portions of organization remain, they appear as if imbedded in a pure bituminous mass. The slaty coal generally preserves traces of cellular or vascular tissue, and the spiral vessels, (*Lign.* 2, 68.) and the dotted cells, indicating the coniferous structure, may readily be detected by the aid of the microscope, in chips or slices. In many examples, the cells are filled with an amber-colored resinous substance; in others, the organization is so well preserved, that on the surface exposed by cracking from heat, the vascular tissue, spiral vessels and cells, studded with glands, may be detected. Even in the white ashes left after the combustion of coal, traces of the spiral vessels are discernible by a high magnifying power. Some

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What is said of the fermentation of hay, and its appearance when the air is excluded? How does this illustrate the origin of coal? What is said of the structure of slaty, bituminous coal?

beds of coal appear to be composed wholly of minute leaves, or partially decomposed foliage; for if a mass recently taken from the mine be split asunder, the exposed surfaces are found covered with delicate pellicles of carbonized leaves and fibres matted together; and flake after flake may be peeled off through a thickness of many inches, and the same structure be apparent.

22. The above experiments and circumstances being deemed sufficient to show that coal is of vegetable origin, and this being our main object at this place, we shall now turn our attention to other subjects, to resume that of coal more particularly in its proper place.

PART I.

CHAPTER II.

FOSSIL REMAINS OF ANIMALS AND PLANTS.

23. HAVING made the foregoing explanations and re marks, we are prepared to take a more extended view of the subject of organic remains, taking the Medals of Creation and Dr. Buckland's Bridgewater Treatise as our guides.

24. The study of organic remains, says Dr. Buckland, forms the peculiar feature and basis of modern geology, and is the main cause of the progress of this science since the commencement of the present century. We find certain families of organic remains pervading strata of every age, under nearly the same generic forms which they present among existing organizations. Such are the Nautilus, Echinus, Terebratula, and various forms of corals; and among plants, the Ferns, Lycopodians, and Palms.

25. *Some families peculiar to given formations.*—Other families, both of plants and animals, are limited to particular formations, there being certain points where entire groups ceased to exist, and were replaced by others of a different character. The changes of genera and species are still more frequent, and hence it has been well observed, that to attempt an investigation of the structure and revolutions of the earth without applying minute attention to the evidences afforded by organic remains, would be no less absurd than to undertake to write the history of any ancient people without reference to documents afforded by their medals and inscriptions, their monuments, and the ruins of their cities and temples.

26. *Zoology and Botany required.*—The study of Zool-

What is said of the importance of the study of organic remains? What is said of Zoology and Botany as preparatory to the study of Geology?

ogy and Botany has therefore become as indispensable to the progress of Geology as a knowledge of Mineralogy. Indeed, the mineral character of the inorganic matter of which the earth's strata are composed, presents so similar a succession of beds of sandstone, clay, and limestone, repeated irregularly, not only in different, but in the same formations, that similarity of mineral composition is but an uncertain proof of contemporaneous origin, while the surest test of identity of time is afforded by the correspondence of the organic remains; in fact, without these, the proofs of the lapse of long periods as Geology shows to have been occupied in the formation of the strata of the earth, would have been comparatively indecisive.

27. *Secrets of nature revealed by organic remains.*—The secrets of nature that are revealed to us by the history of fossil organic remains, form, perhaps, the most striking results at which we arrive from the study of Geology. It appears almost incredible to those who have not minutely examined natural phenomena, that the microscopic examination of a mass of rude and lifeless limestone should often disclose the curious fact, that large proportions of its substance have once formed parts of living bodies.

28. *Large portions of the earth's surface derived from animals.*—The study of these remains has also fully demonstrated that no small part of the present surface of the earth has been derived from the remains of animals that constituted the population of the ancient seas. Many extensive plains, and massive mountains form, as it were, the great charnel-houses of preceding generations, in which the petrified exuviæ of extinct races of animals and vegetables are piled into stupendous monuments of the operations of life and death, during unknown periods of past time.

29. *The deeper we descend, the more ancient the remains.*—The deeper we descend into the strata of the earth, the higher do we ascend into the ancient history of the past ages of creation. We here find successive stages marked by the varying forms of animal and vegetable life, and these generally differ more and more widely from existing

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What secrets of nature are revealed by the study of fossil remains? Whence is a large proportion of the surface of the earth said to be derived? Are the remains at, and below the surface, the same?

species as we go further downwards into the receptacles of the wreck of more ancient creations.

30. *Similar remains exist in similar strata.*—When we discover a constant and regular assemblage of organic remains, commencing with one series of strata, and ending in another, which contains a different assemblage, we have herein the surest grounds whereon to establish those divisions which are called *geological formations*, and we find many such divisions succeeding each other when we investigate the mineral deposites on the surface of the earth. As examples, if we find strata containing the remains of trilobites, whether they occur in the northern or southern quarters of the globe, we may conclude that the formations where they exist are of the same age, and have been formed under similar circumstances and of the same materials; and so, also, of the nautili, echini, or other organic exuviæ.

31. *Most of these remains are extinct.*—The study of these remains presents to the zoologist a large amount of species and genera which are extinct; that is, not known to exist any where in the living state at the present day, but which, at the same time, bear important relations to existing forms of animals and vegetables, and often supplying links, which had hitherto been unknown, in the great chain whereby all animated beings are held together, in a series of gradual connections.

32. *Bearing on natural theology.*—The discovery, amid the relics of past creations, of the links that seemed wanting in the present system of organic nature, affords to natural theology an important argument, in proving the unity and universal agency of a common great first cause; since every individual in such a uniform and closely connected series, is thus shown to be an integral part of one grand, original design. It is true, that the non-discovery of such links would form but a negative and feeble argument against the common origin of organic beings, because, for aught we know, the existence of intervals may, in themselves, have formed a part of the original design; but the existence of such links shows a

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Are similar remains found in similar strata, or not? If a trilobite is found in America, and another in Asia, what do they indicate with respect to the age of the strata? Are these remains of extinct or living genera? How does this subject relate to natural theology?

unity of design, which very clearly proves the unity of intelligence in which it originated.

33. *The lowest orders chiefly prevail in the lowest strata.*—It is indeed true, that animals and vegetables of the lowest orders, prevailed chiefly at the apparent commencement of organic life. Thus we find in the deepest strata, chiefly, the remains of animals of the most simple construction, as the sponges, star-fishes, and corals. And of vegetables, those are rarely found, other than such as belong to the class Cryptogamia, as the ferns, mosses, and fuci, or sea-weeds. In a few instances, however, the bones of fishes, of reptiles, and more rarely of birds and whales have been discovered among the early formations, proving the existence of these tribes at very remote periods.

34. *More recent strata inclose more perfect animals.*—As we ascend towards the surface, and examine more recent formations, we find that remains of the more perfect animals gradually become more abundant, until we arrive at the perfect structures of the saurians, or lizards, the elephants, mastodons, and other Mammalia, some of which belong to existing genera, and all to existing orders.

35. *Shells the most common remains.*—The most prolific source of organic remains is the accumulation of the shelly coverings of animals which occupied the bottom of the sea, apparently during a long series of succeeding generations. A large proportion of the entire substance of many strata is composed of myriads of these shells reduced to small fragments by the long continued movement of the water. In other strata, the presence of countless multitudes of unbroken corallines, and of fragile shells, having their most delicate spines still attached and unbroken, shows that the animals which formed and inhabited them, lived and died undisturbed where these remains are found.

36. *Such strata prove the lapse of time.*—Strata thus formed of the exuviæ of innumerable generations of organic beings, afford strong proof of the lapse of long periods of time, wherein the animals from which they have been derived, lived and multiplied and died, at the bottom

Where do the lowest orders of animal and vegetable fossils chiefly prevail? What remains are found in the more recent formations? What is said of strata formed entirely of shells?

of the seas, which to all appearance once occupied the places of our present continents and islands. Repeated changes of species, both of animals and vegetables, as their remains show, in the succeeding members of the different formations, give further evidence, not only of the lapse of time, but also of important changes in the physical condition, and climate of the ancient world.

37. *Microscopic Shells.*—Besides the accumulations of the larger shells of which we have seen, entire strata are composed, minute examination discloses, especially in chalk and coral formations, immense accumulations of shells, so small as not to be distinguished by the naked eye, the microscope only revealing to the astonished naturalist, immense masses composed entirely of shells, which he had mistaken for particles of sand or earth. Some idea of the number and minuteness of these remains may be obtained from the fact that less than an ounce and a half of limestone afforded an observer 10,454 microscopic chambered shells. The rest of the stone was made up of fragments of larger shells, and of the minute spines of echini, or sea eggs. Masses thus formed, do not consist of a single species, but often contain a variety of species and genera, there being several species known to naturalists, and having their distinctive names, which are so minute, as to weigh, each, only the 500th part of a grain. Indeed, many of them will pass through holes in a sheet of paper, which have been made by a cambric needle of the smallest size. Bd. p. 92.

38. *Marine and fresh water remains.*—In many instances it has been found that lacustrine, fluviatile, and marine remains, or the exuviæ of lakes, rivers, and the sea, have been by some means mingled together in the same strata, and to these have been added the bones of large marine animals, and those of the land. Such phenomena are accounted for by supposing that these accumulations were formed at estuaries, or the mouths of rivers entering the sea, and that the shells were left by the alternate overflow of the salt and fresh water, the marine animals entering from the sea, and those of the land being brought down and deposited by the current of the river.

How do such strata prove the lapse of time? What is said of strata formed of microscopic shells? What is said of the minuteness of some species of shells? In what manner is it supposed that remains from the sea, rivers, and land, were mixed?

CHAPTER III.

ANIMALS SUDDENLY DESTROYED.

39. In the above history of organic remains, there is nothing to prevent the belief that the animals, whether of the sea or land, became extinct, by the ordinary means; as the decay of nature, or disease, by which slow and gradual accumulations were formed, during extended periods of time. It remains to state, that other causes seem to have operated in a few instances, and at distant intervals, to produce a rapid accumulation in certain strata, apparently accompanied by the sudden destruction, not only of the testacea, or shell animals, but also of those of the higher orders.

40. *Destruction of fish at the present day.*—We have apparently analogous instances of sudden destruction, operating locally, at the present time, in cases of fish that perish from an excessive admixture of mud with the water, during extraordinary tempests blowing on the shore, and also by the continuance of uncommon degrees of cold, by which the fish in shallow arms of the sea become torpid, and are floated on shore by high tides, and there left to perish. The excessive heat and noxious gases emanating from volcanic eruptions, have also caused the destruction of vast numbers of marine animals of all classes and descriptions. Another cause of destruction to these animals is the sudden irruption of salt water into ponds or estuaries, previously occupied by fresh water, or the bursting of a lake into an arm of the sea, in either of which cases it is obvious that the inhabitants of each must be destroyed.

41. *Fossil fish not destroyed by mechanical violence.*—In most instances fossil fish present no appearance of having perished by the pressure of the incumbent strata, or other mechanical violence; but rather to have been destroyed by cold, or noxious vapors, or perhaps by heat, or some change in the element in which they live, which caused the rapid extinction of life.

What causes the destruction of fishes at the present day?

42. *Phenomena of the fishes of Monte Bolca.*—The greatest accumulation of fossil fish known, is at Monte Bolca, in Italy, and their remains seem to indicate that they perished suddenly, on arriving at a part of the then existing sea, which was rendered noxious by volcanic agency, and of which the adjoining basaltic rocks afford proof that such agency existed there at some remote period. The skeletons of these fish lie parallel to the laminæ of the calcareous slate in which they are found; they are always entire, and so closely packed together, that some of the blocks are composed mostly of their bones. The thousands of specimens existing in cabinets in every part of Europe and America, have all come from the same quarry. All these specimens were formed by fish, which to appearance, died suddenly at this fatal spot, and were there speedily buried in the calcareous sediment then in the course of deposition. That they were buried speedily, and before any considerable decomposition had taken place, is proved by the fact that some of them still retain the color of their scales and skin. Bd. p. 100.

43. *Accumulation of fossils, owing to the action of water.*—From the account above given of organic remains, and especially the condition in which they are found, being entombed in stratified formations, we must conclude, that not only those originally belonging to the waters, but also those of terrestrial animals, have been accumulated and buried by the action of water. Indeed, we know of no other means by which strata, that is layers of earth one upon the other, can be produced; and with respect to shells and other marine exuviæ, it is quite obvious that this was the means of accumulation. With respect to the bones of land animals, where the entire skeleton is preserved, which is in a few instances the case, this is good evidence of the action of water also; since had the animal perished on the surface of the earth, and there remained for any length of time, the bones would have been detached by decomposition of the flesh, or the appetites of feline animals, and thus individual parts only, would have been found at the same place. Besides, the bones themselves soon loose their animal matter, and decay when exposed to the action of the atmosphere. It is therefore most

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By what causes is it supposed that fossil fishes were destroyed? What reason is there to believe that the fossil fish described, perished suddenly?

reasonable to suppose, that the entire animal was covered in the place where its bones are found, and that this happened soon after death. Perhaps many of the land animals perished by drowning, in consequence of the overflow of rivers, while those belonging to the water were cast on shore by storms, and buried by the same means.

CHAPTER IV.

CONDITIONS IN WHICH ANIMAL REMAINS ARE FOUND.

44. It is true, as above stated, that in a few instances, the entire skeletons of the larger animals have been discovered. But it is the countries of the arctic regions only, which may be expected to afford such phenomena at the present time. Here, in several instances, the entire carcases of colossal mammalia, allied to the elephant, or to extinct species of the rhinoceros, have been found, mostly imbedded in ice.

45. *Sometimes drifted by icebergs.*—It would appear that at some remote period, the carcasses of many large animals belonging to the mammalia, were drifted from the cold regions, probably by icebergs, into temperate climates, where the ice melted, and the bodies either sunk to the bottom of the sea, or were drifted into estuaries, or stranded on the shore; the flesh then decomposed, and the skeletons became imbedded in the sand or earth by the action of the water. In this manner alone can be explained the occurrence of bones and teeth of the rhinoceros, mammoth, hippopotamus, and other large animals, so common in England, Germany, and other countries. These remains, though buried in sand containing pebbles and boulders, water-worn, and evidently transported, are themselves free from attrition, their prominent angles remain-

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Why is it believed that fossil accumulations were made by the action of water? Why is it supposed that the bones of animals were collected and buried by the action of water? In what regions are the entire carcasses of animals found? What is said of icebergs as a means of transporting animal remains?

ing as perfect as when first exposed. Now this could not have been the case, had they lost their coverings, and in this state, been exposed to the united action of the water, sand, and stones, for any considerable time. They would have shown the effects of such action by being worn and rounded, as bones found on the sea-shore do at this day. Says Mr. Mantell, "I have found fossil bones of the horse, deer, ox, and whale, lying in the midst of quartz and granite pebbles and boulders, the bones, though crumbling to pieces if not carefully removed, being *quite perfect*, and the whole mass held together by calcareous spar deposited by water that had during the lapse of ages, percolated through the chalk above."

46. *Bones penetrated by carbonate of lime.*—In most instances, fossil bones, and especially the large ones of the mammalia, are more or less penetrated with carbonate of lime. The extremities of the long bones being porous, after losing their animal matter, nearly always have these portions filled with shining crystals of that mineral. Sometimes detached pieces of bone are held together in this manner, the intervening portions having entirely disappeared.

CHAPTER V.

HINTS FOR COLLECTING FOSSIL BONES.

47. The light, friable, porous bones, require great care in their removal from the deposites in which they are imbedded, whether it be clay, consolidated shingle, or limestone; if of considerable size, they will almost invariably break to pieces, and many examples will not admit of repair. It is therefore always desirable, before attempting to extract a large bone, to make a sketch of it; its form will thus be known, should it be destroyed; and if it

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How do fossil bones show that they have not been exposed to the action of the sea, uncovered? What mineral is usually found in the pores of fossil bones? What is advised before attempting to extract a large bone from its bed?

crack into fragments, that will admit of reunion, the drawing will be a guide for the replacing of the separated parts. If only a few pieces remain, those which show any part of the terminations or joints, should be preserved with particular care, as they show the most precise and important characters, and in the hands of an expert fossil osteologist, will often go far towards determining the order to which the animal belonged. The faithful record of an imperfect or unknown fossil may not be without its value, for as the antiquary carefully preserves the shreds of ancient manuscripts, in the hope that other documents may come to light, by which he may be enabled to interpret these, now unintelligible relics; so the geologist should treasure up every fragment of an undetermined organic remain, for the time may arrive when other specimens will explain its nature, and prove it to possess great interest.

48. *Repairing broken bones with glue.*—The broken porous bones may easily be repaired by thin, hot glue; and when the joinings are set, the whole bone should be saturated with thin glue, well brushed in, and the surface, before the glue congeals, be sponged clean with hot water. When dry, the specimens will be found to possess considerable firmness and durability. By this process, the tusks of mammoths and elephants may be restored, however much crushed; time, patience, and a little dexterity, are only required in many instances, to convert a heap of mere fragments into a valuable relict of the ancient world.

49. *Use of drying oil in repairing bones.*—When the bones are tolerably perfect, but very dry and friable from the loss of their animal oil, they may be made durable by saturating them with linseed, or other drying oil, and then exposing them to a considerable degree of heat. In this manner, the magnificent skeletons of the sloth tribe, the Megatherium, and the Mylodon, in the Hunterian museum, were prepared.

50. *Plaster of Paris another means.*—When a bone appears as if cracked into numerous pieces before its removal from the earth, but still preserves its form, the only

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What part of a bone ought particularly to be preserved? Why? What is said about preserving fragments of unknown broken bones? How may bones be repaired? What use is made of drying oils in preserving bones?

method by which it may be successfully extracted, is by putting over it a thick covering of plaster of Paris, which should be used of the consistence of cream; and when it sets, (which if it be recently prepared, will be in a few minutes,) the specimen may be carefully extricated from the stratum, and the plaster be removed, or not, according to the nature of the fossil, and the parts requiring to be displayed. In many cases, however, the bones are found to be so firmly imbedded, and so brittle, that these means do not succeed, and when of moderate size, therefore, it is best not to attempt their removal from the stone, but to trim the block into a convenient shape and size, carefully cutting away with a chisel, the surrounding stone, so as to expose the most essential part of the fossil. In all cases where this can be done, it is a good method, for such specimens have a double interest, since they at once illustrate the organic relic, and the formation in which it is found.

51. *Roman Cement another means.*—When a bone is too imperfect to be united as a whole, it may be imbedded in Roman cement. This is of easy application, and the fissures and cracks may be filled up with it, taking care first to cover the parts with thin hot glue, or otherwise the cement, as it dries will shrink, and fall out. A thin coating of mastic varnish over the whole, will tend to restore the color, and by excluding the air, to preserve the specimens.

52. *Preservation of fossil teeth.*—The teeth, with the exception of the enamel, have generally undergone the same changes as the bones, with which they are associated. They are often so brittle as to fall in pieces in the vertical direction by the least force. When this happens, the pieces must be joined with glue and held in place by a string, the superfluous glue being removed with a sponge and hot water. If there be any portion of the jaw-bone attached to the tooth, this ought to be carefully preserved, and the earth examined for other portions, and especially the articulations, or joints.

The student, even from this brief review will perceive how many valuable facts may be unnoticed or irretrieva-

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How is plaster of Paris used to assist in the extrication of bones? What is said of Roman cement in repairing fossil bones? Do the teeth of animals decay with the bones?

bly lost, unless attention be given to the various circumstances under which fossil remains are presented to his notice. M. C. p. 56.

CHAPTER VI.

CONDITIONS IN WHICH FOSSIL VEGETABLES ARE FOUND

53. THE remains of the vegetable kingdom are presented to the notice of the geologist in various conditions; in some instances but little changed in their aspect, as in the recent accumulations of mud and silt, at the bottoms of lakes and rivers, and in morasses, and peat bogs; and also in tufaceous incrustations, in which decayed wood, and the leaves of plants, or their imprints, are preserved by being incrusted with calcareous particles. These with the small twigs of trees, well preserved, together with such other matters as are swept together by running streams, are found in semi-solid masses on the borders of brooks coming from limestone districts, and owe their preservation and peculiar appearance, to the deposition o' calcareous matter with which such waters are charged. Such are called *tufaceous* formations, and are common in limestone districts at the present day. In some instances the wood is perfectly sound and the leaves still retain their color, having received their envelope of lime within a few months or perhaps weeks. These, of course, are recent fossils, and therefore are seldom the objects of legitimate geological inquiry, not being mineralized.

54. *Ancient vegetable remains.*—Vegetables found in ancient deposits, have been preserved by various means, as by the permeation of calcareous particles, or of siliceous, or pyritous; in other terms, by lime, flint, or sulphuret of iron. These are called *petrifactions*, and are known severally under the names of *calcareous, siliceous and ferruginous* petrifactions, though the latter is improperly so called, being penetrated with iron instead of stone.

55. *Petrifactions often appear like the original wood.*—It

What are tufaceous incrustations? Are these mineralized or not? What are the kinds of petrifactions mentioned? Is the latter a petrifaction? Why not?

is not uncommon to observe specimens of fossil wood, taken from ancient formations, so nearly resembling the wood itself, both externally and internally, that the casual observer mistakes it for what it once really was, and is only undeceived, when he finds in his hand a solid stone, instead of a specimen of antediluvian wood.

56. In silicified wood, it is not uncommon to find the most minute and delicate structure of the original perfectly obvious, and when placed under the microscope, even the vessels which once conveyed the sap are distinctly seen. Calcareous wood also retains its structure, but being commonly less translucent, than the siliceous, the finer tissues are not so readily observed. In many limestone formations, the leaves and seed-vessels of various plants are particularly well preserved. The ligneous coverings of nuts, and the strobiles, or cones of the pines and firs, are often in a perfect state of preservation, and in some rare instances, even indications of flowers have been detected. The sporules, or seeds, on the leaves of the fern tribe are often seen in specimens of coal-shale from Tilgate forest, in England, and also the resinous secretions of the pines and firs.

57. *Lignite and Coal.*—But vegetables occur not only as petrified stems, leaves, and fruits, associated with other remains in strata, but also in beds of great thickness and extent, consisting almost entirely of plants and their leaves transmuted by that peculiar process which vegetable matter undergoes when excluded from atmospheric influence, and under great pressure, into carbonaceous masses known under the names of *lignite* and *coal.* And there are intermediate stages of this process, in which the form and structure of the trees and smaller plants are quite apparent, as in the peat-bogs and submerged forests of modern epochs, in which the fruits, leaves and trunks of known, and indigenous species are found. From these, a gradual transition may be traced to those accumulations of the extinct species of the ancient Flora, which, at the present day, is one of the great objects of geological research.

What is said of the structure of silicified wood? What parts of plants are found petrified? Besides petrifactions, in what other conditions are plants found? What is said of tracing the vegetables of peat to those of the ancient Flora?

CHAPTER VII.

MICROSCOPICAL EXAMINATION OF FOSSIL PLANTS

58. The microscope is the instrument by which the structure of nearly all natural objects has been made known. The vessels, by which the vital circulation is carried on, are in most parts of animals, too minute to be distinguished by the naked eye, and in plants none of the beautiful mechanism by which they are nourished, and perpetuated can be observed and understood, without the use of this instrument. In fossil wood, as we have already seen (55) the structure is often as perfect as in the original tree, but some preparation of the specimen is required to make it apparent, even when magnified.

59. *Preparation of fossil wood for examination.*—Mr. Nicol, of England, we believe, was the inventor of the method, now generally adopted for this purpose. His description is as follows. Let a thin slice be cut (or chipped) off from the fossil wood in a direction perpendicular to the length of its fibres. The slice thus obtained must be ground perfectly flat and polished. The polished surface is then to be cemented to a piece of plate-glass, three inches long and one wide, by Canada balsam. A thin layer of balsam must be applied to the polished surface of the slice, and also to one side of the glass. The slice and glass are now to be laid on a thin plate of metal, and gradually heated to concentrate the balsam. The heat must not be so great as to throw the balsam into a state of ebullition, for if air bubbles be formed, it is difficult to remove them, and they will prevent the adhesion of the two surfaces. The heat of the metal should not be so great as to burn the fingers. When the balsam on each, is concentrated, the slice and glass are to be applied to each other, with a slight pressure to expel the superfluous balsam. When the whole has cooled, the balsam around the slice must be scraped off with a penknife, and by this it will be seen whether the balsam has undergone the requisite concentration; for, if it flakes off before the knife, it will be found that the slice, and glass will cohere so firmly, that in the grinding, there will be no risk of sepa-

Describe the preparation of fossil wood for the microscope.

tion; but, if the balsam has not been well concentrated, it will slide before the knife, and in that case, the two bodies will not adhere with the requisite firmness. If the layer of balsam be not too thick, its concentration will be accomplished in four or five minutes, if the heat be properly regulated. The slice must now be ground down to that degree of thinness, which will permit its structure to be seen under the microscope. This may be accomplished by rubbing it, by a rapid circular motion with the hand, on a piece of sheet-lead supplied with a little fine emery moistened with water. When the emery ceases to act, the muddy matter remaining should be removed, and a fresh portion applied. This being repeated until the slice is perfectly flat, a sheet of copper is then substituted for the lead, and the fossil ground as smooth as possible, by flower of emery. It is then, and lastly, to be polished with *crocus* or rotten stone, on a transverse section of any soft wood. Being removed and cleaned of the balsam, it is then ready for examination.

CHAPTER VIII.

FOSSIL BOTANY.

60. In the Linnæan system of Botany, the classes are chiefly distinguished by the number, situation, and proportions of the stamens which the flowers contain. The orders are founded on the number of pistils; on the situation of the fruit, or on the kind of pericarp. The genera and species are also known by the number and situation of the stamens and pistils, or some other circumstance in which the flower is concerned.

61. *Fossil Botany founded on the wood and leaves.*—Now it is obvious that the Linnæan system cannot be applied to Fossil Botany, since the plants of the ancient Flora have lost all the distinctive characters, above named, neither their pistils, stamens, nor any other part of their flowers being preserved. It is true that in the class Cryptogamia where the flowers are wanting, or the fructification

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On what are the classes of the Linnæan system of Botany founded? On what the orders, genera and species? Why will not the common system of Botany apply to fossil vegetables.

is so concealed as not to be a guide in their distinctive organs, that the characters of recent plants, may to a certain extent, be applied to fossils of the same class. Thus the ferns of the ancient world, on being compared with those now growing, have in some instances been found analagous, though always of a different species; nor indeed has it been found, in a single instance, that any fossil vegetable could claim arrangement with a known species now growing. How far an agreement could be traced between the ancient and present Flora, had we the means of comparing their organs of fructification, of course cannot be known. It is, however, true that the internal structure of fossil wood, and the impressions left by fossil leaves, show that they did not materially differ in these respects from the wood and leaves of the present day.

62. *Division of the vegetable kingdom founded on the wood and leaves.*—We shall now give such an explanation of what is termed the *natural system* of Botany as will be required at the commencement of the study of fossil vegetables.

There is a distinct and wonderful division of a large proportion of the vegetable kingdom into two grand, but unequal classes, dependent on the structure of the wood or stems, and the leaves of each, the seeds of each class also corresponding with this structure. These divisions are the *Monocotyledonous* and the *Dicotyledonous*. These terms are derived from the number of cotyledons or seed lobes; which the seeds of each contain; the first being derived from the Greek *monos*, single, and cotyledon, and the other from *dis* twice, and cotyledon. Examples of the first are wheat, Indian corn, the sugar-cane, the palms, &c.; of the second, the bean, acorn, chestnut, filbert, &c.

CLASS I. MONOCOTYLEDONOUS PLANTS.

DISTINCTIVE CHARACTERS.

63. *Leaves with parallel veins; stem with no distinction of wood, bark, and pith; cotyledon one, and if two, placed alternately.*—Some of the most striking and obvious distinctions

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Do any of the ancient plants belong to known species? On what are the two grand natural divisions of plants founded? What are the two grand divisions of the vegetable kingdom? On what are these divisions founded? Give examples of each class.

of this class are, that the wood or stem increases on the inside, by general accretion; that the bark is so incorporated with the wood that no distinct separation can be effected; that the wood has no concentric layers, showing the annual growth; and that the leaves have parallel veins. From the circumstance that plants of this class increase from within, they are called ENDOGENOUS plants, from two Greek words signifying *internal increase*, and the class is called ENDOGENÆ.

CLASS II. DICOTYLEDONOUS PLANTS.

DISTINCTIVE CHARACTERS.

64. *Leaves reticulated; stem with wood, pith, bark, and medullary rays; cotyledons two or more, placed opposite to each other.*—The most obvious characters of this class are, that the wood increases by concentric layers on the outside, showing, when cut transversely, annual rings; that the bark and wood are distinct, being readily separated; that the wood has medullary rays; and that the leaves have reticulated, or net-like veins. The vegetables of this class, from the circumstance that their increase is on the outside are called EXOGENOUS, from the Greek, signifying *external increase*, and the class itself is called EXOGENÆ.

ENDOGENOUS, OR MONOCOTYLEDONOUS STRUCTURE.

65. The wood and cellular tissue, in the plants of this class appear to be mixed together, without any order, there being no distinct circles of growth, or radiating medulla, nor is there any pith at the centre. The leaves present no articulations to the stems, leaving scars when they fall off as in the Exogenæ. The leaves are often attached by a large surface, sometimes clasping the stems in a partial circle and never detaching themselves spontaneously, as in Indian corn, wheat, and sugar-cane.

66. *Cellular tissue.*—The stems of both classes are in a considerable proportion composed of cells, but one of the

What are the obvious distinctive characters of the first class. What those of the second? Why is the first class called Endogenæ? Why are the plants of the second class called Exogenous? What is the structure of the wood in the Endogenæ? How does this wood increase? How are the leaves attached. What are examples of this class? What tissue prevails in the wood of this class?

peculiar distinctions between them, is the manner in which they are arranged. In the Endogenæ, the cellular tissue so prevails, that the stems, when cut transversely, appear to be composed of little else than cells and membranes in a confused mass, with strings, or longitudinal fibres interspersed. *Lign.* 1.

LIGN. 1.

Fig. 1.

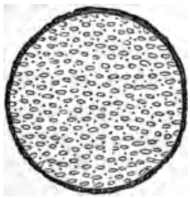
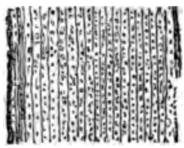


Fig. 2.



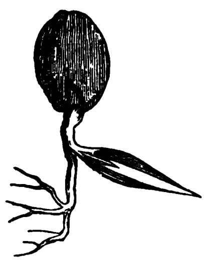
Endogenous Structure.

67. This is shown by *Lign.* 1. *Fig.* 1, which represents the transverse section of a stem of sugar-cane. A stem of Indian corn is perhaps a more familiar example and shows a very similar appearance.

68. The longitudinal structure of the same plant is represented by *Lign.* 1, *Fig.* 2, by which it is obvious that such stems are made up of masses of cells with membranes between them.

LIGN. 2.

Fig. 1.



Endogenous seed.

Fig. 2.

Endogenous Leaf.

69 The monocotyledonous seed, in its germinating state, is represented by *Lign.* 2, *Fig.* 1, maize, wheat, and oats, where the leaves appear a few inches above the ground are examples.

70. The Endogenous leaf is represented by *Lign.* 2, *Fig.* 2. It will be observed that it has a smooth surface, with parallel veins running from one extremity to the other, with little bars between them. This example is from the *Gloriosa superba.*

EXOGENOUS, OR DICOTYLEDONOUS STRUCTURE.

71. As we have seen, the name of this class means "two cotyledons," but in several instances, plants belonging here, as in case of the pines, have four seed lobes. These, however, are only exceptions to a general law. This class is most obviously distinguished from the other, by the concentric rings and medullary rays of the wood; the easy detachment of the bark, and the net-like appearance of the leaves.

LIGN. 3.

Fig. 1.

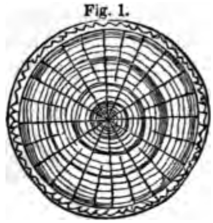


Fig. 2.

Exogenous wood.

72. This structure of the wood is apparent in every log and limb, when sawn transversely and is represented by *Lign.* 3, *Fig.* 1, in which all these parts are apparent.

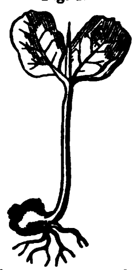
73. The longitudinal structure of the wood is represented by *Lign.* 3. *Fig.* 2. This structure differs from that already described as the *cellular*, in having another set of organs, called the *spiral* vessels, which are not found in the Endogenæ.

What are the most obvious distinctions between the wood of this and the first class? How does the longitudinal structure differ? How do the leaves differ?

74. The Dicotyledonous seed is represented in the germinating state by *Lign.* 4, *Fig.* 1. The bean, acorn, and pea are familiar examples.

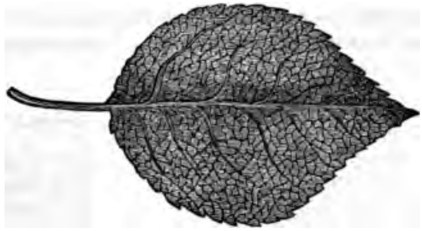
LIGN. 4.

Fig. 1.



Exogenous seed.

Fig. 2.



Exogenous leaf.

75. The reticulated leaf of the Exogenæ is represented by *Fig.* 2. This example is from the apple-tree, and it will be seen that the veins run in every direction, instead of being parallel as in the Endogenæ.

76. To the Monocotyledonous class belong the palms, the cocoa-nut, canes, and many other species chiefly growing in hot climates. All the grasses and lilies also belong here. The Dicotyledonous, includes the oak, chestnut, and walnut, with all the other forest trees of northern climates.

CONIFEROUS STRUCTURE.

77. The cone-bearing trees, as the pines and firs, an extensive and important class, have, as already stated, four cotyledons, and though considered by their growth as belonging to Exogenous vegetables, still, in the structure of the wood they differ from both the other classes, and therefore must be described as a distinct family.

78. In structure, the wood is similar to that of the Exogenæ, already described, consisting of cells, or tubes and membranes ; but in addition to these, the coniferæ exhibit, under the microscope spots or glands as shown by *Lign.* 5, *Fig.* 1. A branch of larch, or pine split longitudinally and

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What important families of plants belong to the monocotyledonous class? What to the dicotyledonous ?

highly magnified exhibits this structure so clearly as at once to distinguish it from either of the other classes; and in the fossil remains of this family. this glandular tissue is so apparent as seldom to mislead the experimenter as to the family to which his specimen belonged. These glands are supposed to be the organs which secrete the resinous fluid on which the odor of this family depends and that exudes in the form of turpentine.

LIGN. 5.

Fig. 1

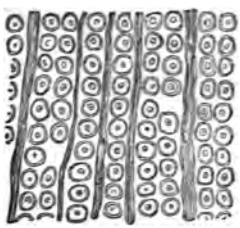
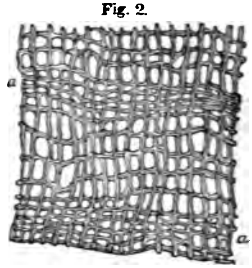


Fig. 2



Coniferous wood.

Besides this peculiar glandular structure, the coniferous family exhibits, in addition to the concentric and radiating lines of Exogenous wood, a system of reticulations, or fibrous crossings exhibited by *Lign.* 5, *Fig.* 2. and by which this family is distinguished from all others. The cross lines *a*, *a*, indicate the annual circles of growth. The structure is somewhat apparent to the naked eye when a pine log is sawn across, but is best seen when highly magnified as in the cut.

79. Among fossil remains of wood, none are said to be so common as those of the coniferous, or pine family, and it is asserted, that in a few instances, these relics of the ancient forests have been found to belong to genera now living, and that others are referred to the genus Araucaria, which comprehends some of the tallest trees now growing, as the Norfolk pine, which sometimes rises to the height of 250 feet.

These discoveries says Dr. Buckland are highly important as they afford examples among the earliest remains

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How does coniferous structure differ from that of the two great classes? What fossil remains of wood are said to be most common? What fossil has been identified with living genera?

of vegetable life of identity in minute details of internal organization, between the most ancient trees of the primeval forests of our globe and some of the largest living coniferæ.

A trunk of Araucaria forty-seven feet long was found in a quarry near Edinburgh in 1830, and another three feet in diameter and twenty four feet long was found in the same quarry in 1833. The longitudinal sections of these trees under the microscope exhibit, like the recent *Araucaria excelsa*, small polygonal discs, arranged in double, triple, and quadruple rows within the longitudinal vessels. A specimen of the same fossil from New Holland exhibits the same structure, indicating the wide extent of this genus in the forests of the ancient world.

80. It appears that the coniferæ are common to fossiliferous strata of all periods; they are least abundant in the transition series, more numerous in the secondary, and most frequent in the tertiary series. Hence we learn that there has been no time since the commencement of terrestrial vegetation on the surface of the globe, in which large coniferous trees did not exist; but our present evidence is insufficient to ascertain with accuracy the proportions they bore to the relative numbers of other families of plants in each of the successive geological epochs, which are thus connected with our own, by a new and beautiful series of links, derived from one of the most important tribes of the vegetable kingdom.

CYCAS FAMILY.

81. This is a small order of curious plants differing in some respects from all others. Linnæus had arranged them with the palms, but Brown suggested their analogy to the Coniferæ, while Brongniart proved by their ligneous structure that they belonged to that family. The Cycas and the pines form a Botanical family, peculiar to themselves in one respect, viz. that their seeds are naked, or without covering of any kind, and hence they are called Gymnospermous, (*naked seeded.*)

In respect to the ligneous structure, the Cycas differs from all other vegetables, combining in certain features

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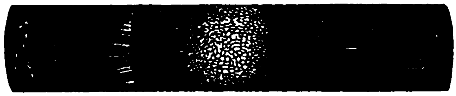
What is said of the prevalence of coniferous trees during ancient periods?
What are the Botanical relations of the Cycas family?

LIGN. 6.



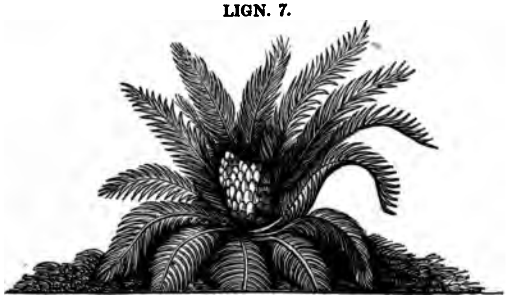
Cycas Structure.

the Exogenæ, the ferns, and the pines. A slice, or transverse section of this plant is represented by *Lign.* 6, having a central pith with woody layers separated by a condensed line, and consisting of elongated cellular tissue, arranged in a regular series, with medullary rays and bark.

ZAMIA.

82. The family Cycadeæ comprehends two living genera, the Cycas and the Zamia, of which there are five known species of the former and about seventeen of the latter. Not a single species of either are indigenous in any part of Europe, being found only in hot climates, as equinoctial America, West Indies, India, &c. They are common in hot-houses, where they excite attention by their peculiar appearance, having a large depressed body, or trunk, resembling a pine-apple, with a tuft of leaves arranged on long stalks, springing from near the top, and resembling at once the palms and the ferns.

LIGN. 7.

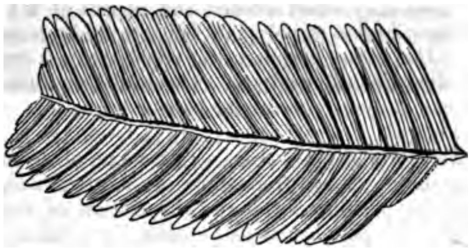


Zamia spiralis.

The Zamia spiralis, from Australia is represented by *Lign.* 7. This will give a good idea of both species, the Cycas being of similar form and habit.

What is the ligneous structure of this family? What is said of the Zamia, and to what family is it allied?

LIGN. 8.



Zamia leaf.

A leaf of the fossil Zamia is shown by *Lign.* 8. This was a very perfect specimen from the Stonesfield slate in England, being nine inches long.

CLASS CRYPTOGAMIA.

83. This is the last class of the Linnæan arrangement, and contains all such plants as have no perceptible organs of reproduction, and consequently cannot be arranged in any of the other classes. It is necessary to give some account of the peculiarities of this large family here, for the use of the student in fossil botany, who is not well acquainted with the science generally, since a large proportion of the fossil vegetables found in the lower strata belonged to this class.

The principal families belonging to this class are the Ferns, Equisetums, Lycopodiums, Lichens, Liverworts, Sea-weeds, or Algæ, and the Fungi, or mushrooms.

FERNS.

84. The family of ferns, says Dr. Buckland, both in the living and fossil Flora, is the most numerous of vascular Cryptogamous plants. Our knowledge of the geographical distribution of existing ferns, as connected with temperature, enables us to appreciate the information to be derived from the character of fossil species, in regard to the early condition of the climate of our globe.

The total number of known ferns, now growing in dif-

Where is the Zamia found? Why cannot cryptogamic plants be classed except by themselves? What are the principal families in cryptogamia?

ferent parts of the world, amount to about 2,000. In north ern climates they never exceed the height of a few feet, the common brake, or polypody being a medium specimen in size. But in hot climates, the arborescent, or tree ferns, assume the size of forest trees. One standing on the staircase of the British museum, is 45 feet high, and is a native of Bengal.

85. *Structure of the Ferns.*—The stems of arborescent ferns are distinguished from those of all other endogenous trees, by the peculiar form and disposition of the scars from which the petioles, or leaf-stalks, have fallen off. In the palms, the leaf-stalks embrace the stem, and leave broad transverse scars, or rings, whose longer diameter is *horizontal.* In case of the ferns alone, the scars are either elliptic or rhomboidal, and have their longer diameters *vertical.* Several of the other families of the cryptogamic class are found in the fossil state, especially the equisetums, and the lycopodiums, or club-mosses, and occasionally the fuci or sea-weeds, and the lichens. The fuci are called Agamous, that is, without sex, as they have no seeds.

CHAPTER IX.

MODE OF INVESTIGATING FOSSIL PLANTS.

86. HAVING thus given such an epitome of the Botany of the classes and orders of plants as are most commonly found in the fossil state, as is required by the student at the commencement of his inquiries, and having also given such illustrations and descriptions of the structure of each class and family, as our limits will admit, we now proceed to describe the methods of applying this information in discriminating the objects in question, according to the directions of the *British Fossil Flora.*

87. The authors of this work, Lindly and Hutton, say, "That a few isolated, and often-times very imperfect data, exclusively afforded by the remains of the organs of vege-

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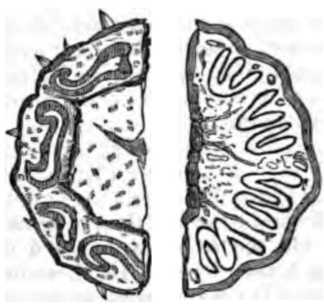
What is a common example of the ferns of our country? What is said of arborescent ferns?

tation, are the sole guide to the class, order, or genus of the fossil plant which the geologist has to examine; hence a general idea only can often be obtained of the original." As already stated, (61,) no part of the flower is found, and therefore our knowledge of the character of the fossil must depend on the examination of the structure, or organization of the wood and leaves.

88. *Examination of the trunk or stem.*—Observe whether a transverse section of the petrified trunk or stem is disposed in concentric circles, as shown by *Lign.* 3: if so, it belonged to an exogenous tree. If, on the contrary, the wood seems to have been deposited in irregular spots, *Lign.* 1, it is endogenous. If a transverse section show remains of sinuous, unconnected layers, resembling arcs, or crooked lines with their ends directed outwards, these arcs being of a solid structure, and imbedded among looser tissue, *Lign.* 9, then it belonged to an arborescent fern, sections of which the cut shows.

LIGN. 9.



Section of fern.

89. If the stem be in a state of preservation, so that .. will admit of slicing or chipping off a piece for microscopical examination, by the process already described, (Chap. VII.,) that should be employed. If the structure be entirely cellular, and it can be ascertained that it never pos-

If a section of wood is disposed in concentric circles, where does it belong? If disposed in irregular spots, where does it belong? If the solid part resembles arcs in loose tissue, what is inferred? If the specimen be entirely cellular, what is inferred?

sessed vascular tissue, the plant belonged to Cryptogamia as the fuci, mosses or lichens.

90. If the specimen consists of parallel tubes, having neither pith nor rays passing from the centre to the circumference, the original was endogenous, and probably belonged to the palm family. If, however, any traces of tissue be detected crossing the longitudinal tubes at right angles, radiating from the centre towards the circumference, this will prove the existence of medullary rays, and the tree must have been exogeneous, as the oak or chesnut.

91. If the transverse section shows a central pith, with layers separated by a condensed line, with elongated cellular tissue, and faint rays, *Lign.* 6, the original belonged to the Cycas or coniferous family.

If the tubes of a longitudinal section be studded with glands, and has medullary rays, with signs of concentric circles, *Lign.* 5, it undoubtedly belongs to the coniferæ, or pine family.

92. If any vestige of central pith be discovered, the exogenous nature of the original may be inferred; and if, in addition to this, signs of a true cortical investment or bark be discovered, there is no doubt but the tree belonged to the Dicotyledonous class; while a cortical investment, or rind, not separable from the inclosed structure, indicates the endogenous class, and the entire absence of any rind shows the cryptogamia.

93. *Marking of the stems.*—The markings on the stems, occasioned by the scars, or spots left by the separation of the petioles, or leaf-stalks, afford important evidence with respect to the class to which the tree belonged, since they are present when the trunk is flattened by compression, even to a thin layer of coal. By these markings it can be seen whether the leaves were alternate or verticillate, opposite or spirally disposed, or whether they clasped the stem horizontally, or extended vertically up and down the stem. It will also be apparent whether the leaf was cast off annually, as in deciduous trees, leaving a clean scar, or whether it was broken off by force, showing the marks of

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If of parallel tubes, without pith or rays, where is its place? What are the marks of the Cycas? What those of the pine? If a central pith be seen, where does it belong? If the rind be absent, where is its place? What can be inferred from the scars of the leaves on the stems of fossil plants?

rupture, by leaving a part of the footstalk, or taking with it a portion of the bark.

94. *Examination of the leaves.*—In the fossil state, the texture and surface of the leaf are sometimes preserved, though, in general, the outline and its divisions, and the arrangements of its veins, can only be ascertained. The *venation*, that is, the form and distribution of the vascular tissue, or veins of the leaf, is the most important character which the geologist can have for his guidance.

95. If the veins are parallel, not branched, but only connected by transverse bars, the leaf itself being undivided, *Lign.* 2, as in the lily and maize, the plant was probably endogenous; but if the leaf be divided, as shown by *Lign.* 8, it must be referred to the Cycas, or Zamia.

96. Leaves having the veins of equal, or nearly equal thickness, and dichotomous, or forked, the leaves themselves being small, with fine veins, and pinnated; and especially if the sporules or seeds have left dots on the back of the leaf, or frond, the specimen clearly belonged to the fern tribe.

97. If the veins be obviously of unequal thickness, that is, largest towards the petiole, and smaller towards the apex, or disposed in net-like meshes, (reticulated,) as in the rose and apple, *Lign.* 4, *Fig.* 2, the tree was undoubtedly dicotyledonous.

98. Leaves of large size, having no veins and irregularly gashed or divided, are probably of marine origin, and are of the fuci family.

According to the authority of the *British Fossil Flora*, and the *Medals of Creation*, such are the rules for the investigation and interpretation of the characters of the stems and foliage, which have been preserved by mineralization. Their application, it is said, is not difficult; and the student may, by their assistance, obtain some general indications as to the nature of the original tree, or plant, whose petrified remains form the subject of his examination.

What is said of the venation of fossil leaves? If the veins are parallel where did it belong? If the veins are parallel, but the leaf divided, what is inferred? What are the indications of the ferns from the leaves? If they are reticulated, where did they belong? If large and gashed and veinless, where?

CHAPTER X.

DURABILITY OF THE FERNS.

99. The great preponderance of the ferns, and of the higher orders of the cryptogamic plants, in the Flora of the ancient world, having excited, in a peculiar degree, the attention of naturalists, and it being conceived that the total absence of certain kinds of plants, and the constant presence of others, with other points of the like nature and interest, might be accounted for by a difference in the capability of one plant to resist the action of water beyond another, Dr. Lindly resolved to try the result by actual experiment.

100. He therefore, on the 21st of March, 1833, filled a large iron tank with water, and immersed in it 177 specimens of various plants, belonging to the more remarkable natural orders, taking care, in particular, to include representatives of all those which are constantly present in the coal measures, or as universally absent. The vessel was placed in the open air, left uncovered, and was untouched, with the exception of filling up the water as it evaporated, till the 22d of April, 1835, that is, for rather more than two years. At the end of that time, what remained was examined, when the following highly curious results were obtained.

101. In the first place, it was found that the dicotyledonous plants had in general wholly disappeared, whence it was inferred, that they could not remain for two years in water without being totally decomposed. On the contrary, the principal part of those found in an undecayed state, were the coniferæ and cycadeæ, which are the very individuals found best preserved in the fossil state.

102. Secondly, it seemed that monocotyledonous plants survived to a considerable degree; whence it was con cluded that they are more capable of resisting the action of water, and in particular the palms, than the exogenous

What was Dr Lindly's experiment to test the durability of plants in water? What was the result? Did it agree with what is known of the durability of fossil plants? What is said of the durability of monocotyle donous plants?

tribes, which again agrees with their fossil relics; but the grasses and sedges had perished; whence it was concluded, that although none of these may be found as fossils, still we have no right to infer that the earth, in the primeval state, was not clothed with the grasses, since there is reason to believe, that had this been the case, they might have entirely disappeared.

103. Thirdly, the fungi and mosses, and all the lower forms of vegetation, were not to be found, and even the equisetums, though of considerable size, left no traces behind.

104. Fourthly, the ferns appeared to have the greatest power of all the plants tried, to resist the decomposing effects of water, especially if immersed in the green state, for not one of them had disappeared during the experiment; there being no decay, except that the spots of fructification had disappeared, a result often, if not constantly, met with in the fossil state.

105. From these experiments, Dr. Lindly assumes, as a general result, that the numerical proportion of different families of plants found in the fossil state, throws no light whatever upon the ancient climate of the earth; but that the species and numbers found, depend entirely upon the power which particular families may possess, by virtue of the organization of their cuticles, or otherwise, of resisting the action of the water in which they floated previously to their being fixed in the strata in which they are now found. Bd. 308.

CHAPTER XI.

SUBMERGED FORESTS, PEAT AND LIGNITE.

106. WE shall precede our description of individual fossil plants, by an account of the effects of water and pressure on vegetables, tracing the transition from peat to lignite. It will be remembered that the coal fields, besides

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What of the grasses? What inference not necessary, because no vestiges of grass are found? What of the fungi and mosses? What of the durability of the ferns? What does Dr. Lindly assume from his experiment?

owing their existence to vegetables, are at the present day the great depositories of organic fossil remains, and hence the interest which geologists have always taken in every thing concerning these formations. In a nation dependent entirely on this source for fuel, and where vast excavations are increased every year by the unremitted labor of thousands of men, constant opportunities are afforded for men of science to make new discoveries, and detect new objects of geological interest. And where the most untiring ardor, wealth, and science are combined to carry forward such investigations, and give the world the result, as is at present the case in Great Britain, other nations, not possessing such advantages, must look to this source for at least the elements of most that is known on geology at the present day. And this is indeed the case, for the English are doing more at present to make geology, as a science, interesting, understood, and appreciated, than all the rest of the world.

107. The phenomenon of extensive tracts of marsh lands, having layers of prostrate trees of all ages, lying but a few feet beneath the common alluvial soil, is of frequent occurrence, both inland and along the shores of the sea in various countries. These submerged forests are often situated below the level of the sea, and thus afford, says Mr. Mantell, unquestionable proof of the subsidence of the land at the places where they are found. The trees are readily distinguished, and are of the kinds indigenous to the districts in which they occur; and leaves and seeds of the hazel, beach, elm, and other trees are often preserved in the silt, (fine sand and clay left by running water,) in which the prostrate forests are engulfed.

108. The wood in these cases has undergone no change but that of being dyed black, from the impregnation of iron, which, combining with the tannin of the plants, forms an ink, that in its turn stains the materials of which it was made. Many of the trunks are as sound as when submerged, and are not unfrequently taken up and employed in building. The oak of the ship Royal George, lately raised up off Portsmouth, England, after being immersed more than sixty years, was perfectly undecayed, and closely resembled in color and appearance, submerged wood.

What is the inference with respect to the land where submerged forests are found? Are the trees of known species, or not?

Associated with these buried vegetables, the bones of deer and swine are occasionally found, and the canoes and stone implements of the aboriginal inhabitants.

109. In the extensive peat bogs of Ireland, large forest trees are often buried, together with the skeletons of elk, deer, and other animals of the chase, and sometimes the bodies of the primitive hunters, wrapped in skins. In Belfast Lough, a bed of sub-marine peat is situated beneath the ordinary level of the waters, and in which the trunks and branches of trees, with vast quantities of hazel-nuts are imbedded in the peat; the whole being covered by layers of sand, shells and silt.

110. In most cases the nut-shells of peat bogs are empty, the kernels having decomposed, and by some means escaped; but in some instances their places are filled with calcareous spar, the outside being still entire, and without a particle of the spar adhering to it.

111. *Age of Peat.*—In all cases peat appears to have been formed since the present order of things, or since the deluge, while it seems equally true that coal of all kinds, including lignite, was formed before that epoch. Hence some geologists have inferred that in process of time, peat bogs would become coal fields.

112. *Antiseptic power of Peat.*—It appears, from the following account, that peat has the power of preserving animal matter from putrefaction and decay.

In the year 1675 two persons, a farmer and a woman, were crossing the peat moors, in Derbyshire, when they were overtaken by a storm of snow, and both perished. This happened in January, and in May, the bodies being found, were buried on the spot. Here they lay twenty-eight years and nine months, when the curiosity of some persons, probably having heard that peat would preserve dead bodies, induced them to open the graves, and this they found to be true; for the bodies appeared quite fresh, the skin fair, though somewhat darker than natural, and the flesh as soft as that of persons lately deceased. These bodies were afterwards often exhibited as curiosities, until the year 1716, forty-one years after their deaths, when they were finally buried by the order of the farmer's descendants. At this time a medical man, who examined

What is said about the age of peat? What of the age of coal? What have geologists inferred with respect to peat bogs?

these bodies, says, that the man was perfect; his beard was strong, his hair short, and the skin hard, and of the color of tanned leather. The body of the woman was not so perfect, but her hair was like that of a living person.

113. At the battle of Solway, in the time of Henry VIII, (1546,) when the Scotch army was routed, an unfortunate troop of horse were driven into the Solway morass, and, sinking down, men and horses, the surface closed over them. A tradition of this catastrophe has always been kept alive by the people of the neighborhood, and the place where it was supposed to have happened, designated. This tradition has been authenticated within the memory of man; a man and horse, in complete armor, such as was worn in Henry's time, having been found by the peat diggers, in the place where it was believed the accident occurred. The bodies of both man and horse were well preserved, and the different parts of the armor readily distinguished. These cases are from different authorities, but are well authenticated.

114. *Causes of the Antiseptic property of Peat.*—This property has been attributed to the carbonic and gallic acids, which are set free during the partial decay of the vegetables, and also to the gums and resins which various plants contain. Others have attributed this effect to the tannin which it is well known peat contains. It is most probable, however, that this property is owing to the formation of pyroligneous acid during the decomposition of a part of the plants, when first immersed, and by which the others, as well as animal matter, are preserved. It is true that we can make this acid only by destructive distillation of the wood; still, it may be conjectured that the natural destruction of the same organic substances may produce the same effect.

LIGNITE, BROWN COAL, CANNEL COAL.

115. The carbonized wood known by these names often exhibits an obvious ligneous structure, so that some specimens appear similar to the imperfectly burned wood in the process of making charcoal. Its chemical characters are

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What is said of the antiseptic property of peat? What facts are cited in proof of this quality? What is this property attributed to? What is lignite?

between wood or peat and perfect mineral coal, having the bituminous odor of the latter, and the texture and inflammability of the former. It is generally deposited among the newer strata, but is sometimes also found in the older tertiary formations; it is not unfrequent in some of the ancient secondary deposits, and may occur in the earliest sedimentary rocks which contain organic remains.

116. The newer deposits of brown coal are commonly situated in depressions, or basins, as if they had been produced by the submergence of woods and forests, beneath a swamp or morass. Specimens often exhibit the carbonized ligneous structure passing into a pure black coal, differing in no respect from pure coal, except that its weight is less.

117. The Bovey coal is in the state of bituminized wood, the vascular tissue, which is often coniferous, being very apparent. It is easily chipped, or split, and it leaves a considerable quantity of white ashes when burned. The layers of coal differ from one to three feet, and there are eighteen or twenty in a depth of 120 feet; this coal field extends seven or eight miles. No fruit or leaves have been found in this formation. Calcareous spar and sulphuret of iron prevail in many of the strata. In some places this brown coal is covered by a bed of peat, in which trunks and cones of firs are found. The whole series of strata appears to have been a lacustrine deposit, into whose basin rafts of pine wood were drifted by periodical land floods.

118. The brown coal formation on the bank of the Rhine presents the same phenomena, on a more extended scale, and complicated with changes induced by volcanic action. In Iceland, where at the present time forests, or even trees are unknown, there are extensive deposits of lignite of a peculiar kind, called *surturbrand,* which serve the inhabitants for fuel, or otherwise that country would be uninhabitable.

119. That well-known and beautiful substance called *jet,* is a compact black lignite, and the vascular tissue may be detected even in the most solid masses, when prepared in thin slices, and submitted to the microscope in the

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What are the chemical properties of lignite? What is the appearance of lignite? What is said of Bovey coal? **What is said of lignite of Iceland?** What is the origin of it?

manner described. When made very thin, it appears by transmitted light of a rich brown color.

120. There are many localities of brown coal in England, and in other parts of Europe: and in our own country the town of Limerick, in the state of Maine, affords an extensive bed. In this instance the coal, which is similar to cannel coal, appears to be now forming, being found at the depth of only three or four feet, and amidst the remains of rotten logs of wood, and *beaver sticks*, that is, limbs gnawed by beavers. The peat is twenty feet thick, and rests on white sand. Some specimens were found highly bituminous, yielding seventy-two per cent. of bitumen. Polished slices of this coal exhibit the peculiar structure of coniferous wood, and prove that it was derived from a species allied to the American fir. M. C. p. 82.

Having already shown (16 to 21) the vegetable origin of coal, it is unnecessary to recapitulate here the proofs already adduced on that subject; the object of the above remarks on peat and lignite being rather to show the effects of time and moisture on vegetables preparatory to entering on the description of individual fossils, than to treat of the origin of coal.

CHAPTER XII.

GEOLOGICAL FORMATIONS

121. Before proceeding further on the subject of organic remains, it is necessary to give the names and relative position of the strata in which they are found. This will be followed hereafter with a description of the individual rocks and deposits, the arrangement and materials of the different classes of strata being inserted here with reference to the fossils they contain, an account of which is to follow.

ARRANGEMENT OF STRATA AND ROCKS.

FOSSILIFEROUS DEPOSITS.

122. The tabular view which follows will give a general idea of the various formations, with respect to their

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How is it proved that it originated from wood?

order of succession, their composition, and the fossils they respectively contain. It may be considered a chronological arrangement, beginning with the most recent formations and proceeding downwards to the most ancient.

I. ALLUVIUM.

I. DRIFT, OR MODERN ALLUVIUM.

123. This includes the deposits now in the course of formation, or the sand left by rivers and lakes, as well as peat bogs, coral limestones, volcanic products, and the tufaceous or calcareous incrustations from mineral springs.

II. DILUVIUM.

124. Containing the bones of animals, often of colossal size, as those of the mastodon, the mammoth, rhinoceros, hippopotamus, elk and whale. These accumulations also contain boulders, and other drifted materials, and by some geologists are supposed to be the effects of the Noachian deluge. The tusks and bones of elephants, found in such vast quantities in the northern hemisphere, are supposed to have been buried during this period. Hence these are called *diluvial* accumulations.

II. TERTIARY FORMATIONS.

III. FOSSILIFEROUS GROUP.

125. This is an extensive series, comprising, often, vast accumulations of marine, lacustrine and fluviatile deposits, as shells, sand, boulders, plants and the remains of animals, both of extinct and of existing species. During this period the earth was rent by volcanoes and tremendous floods, both of fresh and salt water.

Mr. Lyell has divided the Tertiary period into three distinct sub-periods, depending on the ages of the organic remains they contain. These are the—

(*a.*) *Pliocene* (*more recent.*) The strata of this period contain remains, chiefly shells, of which about ninety per cent. are recent, or now living.

(*b.*) *Miocene* (*less recent.*) The strata of this period

What does the modern alluvium include? What do the beds of diluvium contain? What do the tertiary formations include? What are meant by the pliocene, miocene and eocene periods?

contain about twenty per cent. of recent shells, the remainder being extinct.

(*c.*) *Eocene* (*dawn of recent.*) So called because, during this period, the first recent shells appear, being about five per cent. They are found in the London clay, Paris basin, &c.

III. SECONDARY FORMATIONS.

IV. THE CHALK, OR CRETACEOUS GROUP.

126. A marine series of formations, including strata of limestone, sandstone, marls and clays; and abounding in marine organic remains of shells, mollusca, corals, fish, turtles, crocodiles, and other extinct fossils. The remains of *birds* are also found in this group.

V. THE WEALDEN FORMATION.

127. This is a peculiar fresh-water deposit in England, apparently the delta of an ancient river. It contains beds of sandstone, clays and limestone, with occasional layers of lignite, and is particularly characterized by the remains of peculiar aquatic reptiles, viz. Iguanodon, Megalosaurus, Plesiosaurus, Crocodile and Turtles. It also contains endogenous plants, with petrified remains of the cycadeæ and coniferæ. Clays and limestones, almost wholly composed of fresh-water snail-shells and minute crustacea, occupy the upper place in the series.

VI. THE OOLITE FORMATION.

128. A marine deposit of great extent and thickness, consisting of limestone and clays, which abound in marine shells, corals, fish, reptiles, both of terrestrial and marine species, together with the remains of land plants, and of two genera of peculiar animals of the *marsupial*, or pouched order.

This formation has many localities in different parts of England, and in other countries. It is often known under the name *roe-stone*, the masses being formed of small globular calcareous bodies, resembling the roe of fishes. This structure is, however, only partial, the great body of the Oolitic system being common limestone.

What is the chalk, or cretaceous group? What is the Wealden formation? What is the oolite formation, and what peculiar animal remains does it contain?

VII. THE LIAS FORMATION.

129. A series of limestones, clays, shells and marls, in which are contained marine shells, fishes, plants, and especially the remains of two genera of reptiles, the Ichthyosaurus and Plesiosaurus. It is divided into the *upper* and *lower* Lias, each containing particular species of shells or fishes. The term, lias, is a contraction of *layers*, because parts of this system are in thin strata.

VIII. SALIFEROUS, OR NEW RED SANDSTONE SYSTEM.

130. A marine formation, consisting of marls, sandstones, often of a red color, and occasionally variegated. It contains gypsum, rock-salt, with corals, mollusca, plants, fish and reptiles.

It is divided into *upper new*, and *lower new*. The first contains variegated red, blue and white marls, and variegated sandstones. Thickness, 900 feet. The lower new, contains red and white marls and *dolomite;* also, magnesian limestone, sandstones and conglomerates, with the remains of shells, fishes and plants. It is named *saliferous*, because it contains saline materials, as salt and brine. Thickness, 300 feet.

IX. THE CARBONIFEROUS, OR COAL SYSTEM.

131. Consisting of shells, clays, ironstone and limestones, interspersed with beds of coal, sometimes of great extent and thickness; also, innumerable remains of marine and fresh-water fish, as well as plants and animals of tropical species. In this formation most of the fossil remains of plants have been found, which are figured in books, and on which systems of Fossil Botany have been founded. In this system also belong the *coal measures* or coal fields from which such vast quantities of fuel are extracted.

X. THE DEVONIAN, OR OLD RED SANDSTONE SYSTEM.

132. It is a marine formation, containing red and green marls, limestones, sandstones, shells, corals and fishes.

What is the lias formation, and what does it embrace? What is the saliferous system? What does it contain? Why is it so called? What is the carboniferous system? What does it chiefly contain?

Also, flagstones, shales, and concretionary limestones, called *corn-stones*. The color is a dull red, whence the name. It is also called *Devonian*, because it is so largely developed in Devonshire, England.

XI. THE SILURIAN SYSTEM.

133. A marine group, consisting of limestones, shales, sandstones, slates, flagstones, and abounding in corals, shells, trilobites and remains of fish. This is divided into the *upper* and *lower* Silurian, the first being in thickness about 4,000 feet; the second, 3,500 feet.

This system of formation is called *Silurian*, from an ancient tribe of Britons called *Silurus*, who inhabited the region where these strata are most distinctly developed. It is very extensive, including the border countries both of England and Wales.

XII. THE CUMBRIAN, OR SHISTOSE SYSTEM.

134. A marine formation, comprising vast beds of slate rocks, with dark-colored limestones and sandstones, containing a few corals and shells. This system extends over a large portion of Cumberland and Westmoreland, reaching to the elevation of about 3,000 feet. Vast quantities of slate are taken from these rocks for the covering of roofs, and other economical purposes.

IV. PRIMARY, OR HYPOGENE ROCKS.

XIII. MICA SLATE.

135. It consists chiefly of mica, and small particles of quartz, forming strata of various thickness. No fossils are found in this rock.

XIV. GNEISS.

Formed of the component parts of granite, mica, quartz and feldspar, fine grained and laminated, so as to have the appearance of disintegrated granite, again reformed by the agency of water. Both mica-slate and gneiss are supposed to have been altered by heat after they were deposited in their present forms.

What are the elements of the Devonian group? What are chief minerals in the silurian system? What is the shistose system? What are the materials of gneiss?

V. PLUTONIC, OR CRYSTALLINE ROCKS.

XV. THE GRANITE SYSTEM.

136. Granite is one of the most extensive geological formations. It is composed of quartz, mica and feldspar, always in the form of crystals, sometimes of large size. It is supposed to owe its present form to the agency of heat, of which the proof will be adduced hereafter. Granite, gneiss, and mica-slate form the vast elevated ranges of mountains in all primitive countries. Granite is never stratified.

VI. VOLCANIC ROCKS.

XVI. LAVA, BASALT, GREENSTONE, PUMICE, TOADSTONE.

137. These are the products of volcanic action, under various circumstances, and perhaps by different degrees of heat, or the different materials on which the fire acted. Extensive ranges of mountains are composed of these materials, especially of trap or greenstone. These products are of all ages, and are found in nearly every country. They will be considered in detail in their proper place.

HYPOGENE ROCKS.

138. Hypogene is a term coming from the Greek *hypo*, under, and *ginomai*, to be formed, and has reference to the production of granite, and other rocks, formerly called *primitive*, because these rocks are supposed to have been formed under the surface, and afterwards forced up to the situations they now occupy. This term by recent writers is substituted for primitive, because some members of the latter class are supposed to have been posterior to many secondary or fossiliferous rocks.

METAMORPHIC ROCKS.

139. This is a stratified division of the Hypogene group, embracing gneis and mica-slate, which are so named be-

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What its form? What is granite? What its form? What are the volcanic rocks mentioned? What is meant by hypogene? Why is this term substituted for primary?

cause they are supposed to have been altered by plutonic, or calorific action. The word is from *meta*, trans, and *morphe*, form.

CHAPTER XIII.

ILLUSTRATIONS OF FOSSIL BOTANY.

140. HAVING thus given a general history of organic remains, together with lignographs of the internal structure of such classes or orders of trees as are most commonly found in the fossil state; having also named and described the formations in which such fossils are found, we are now prepared to illustrate these classes or orders, by figures of plants, chiefly from the formations named. The design of this work will, however, only allow examples to be given of the different orders, together with perhaps a few varieties from the great number of ferns which have been figured and named by geological writers. It is only necessary to add, that for the figures and descriptions which follow, we are chiefly indebted to the *Medals of Creation*, though the descriptions are generally much abridged.

AGAMIA.

141. The plants of this class have no seeds, or traces of fructification, their structure consisting of cells alone. The fuci, or sea-weeds, of which there are a great number of varieties, belong here.

ALGEÆ.

The Algeæ is a family which includes the fuci, many species of which are found in the mineral kingdom. In the Silurian limestone of the Alleganies, Dr. Harlan found entire layers of rock, mostly formed of a large species of fuci. An individual of this family, the *Fucoides Lamourouxii*, is represented by *Lign.*10. It is from Monte Bolca, and lies on the layer of shale, as taken from the quarry.

What are the agamia? What common plants belong here? What are the algeæ?

LIGN. 10.

Fossil fuci.

CONFERVA.

142. This is a small fresh-water plant, consisting apparently of bundles of green fibres. It is among the lowest orders of vegetation. This, with the mosses, are occasionally found in the fossil state, especially in the tertiary strata. One of these is represented by *Lign.* 11, *Fig.* 1. It consists of a beautiful specimen of green moss, apparently of the genus *Hypnum*, with a conferva twisted around its base, and running towards the apex. This is in a transparent piece of quartz, and forms a remarkably beautiful specimen. It is here magnified three times. Quartz pebbles, including mosses, are known under the name of ***mocha stones***, and are highly valued by collectors.

What is the conferva?

LIGN. 11.

Fig. 1

Hypnum in quartz.

Fig 2.

Equisetum.

CRYPTOGAMIA.

143. A description of this class has already been given (83,) and we shall proceed to illustrate some of the orders there mentioned.

EQUISETUM.

The equisetums, better known under the name of *horse-tails*, are upright, slender and elegant plants, of half an inch in diameter, and about two feet high, growing in moist places. The stems are jointed, each joint having a whorl of linear leaves, and a dentated membranous sheath, embracing the stem.

A gigantic species of this tribe is common in the oolite of Yorkshire, the *Equisetum columnare*, represented by *Lign*. 11, *Fig*. 2. It is an extinct species, being several inches in diameter, and having regular and beautiful columnar marking on the stem.

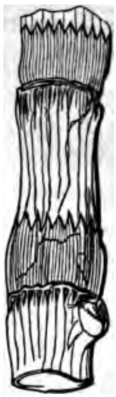
144. Another Equisetum, of smaller size, being about that of those now growing, is represented by *Lign*. 12, *Fig*.

What are the equisetums? How do the fossil equisetums differ from the common?

1. It is the *E. Lyelli*, from the Wealden formation, (127.) This stem, with its two dentated sheaths, closely resembles the recent species, *hyemale*, so common in our moist grounds. It has a bud near the lower joint.

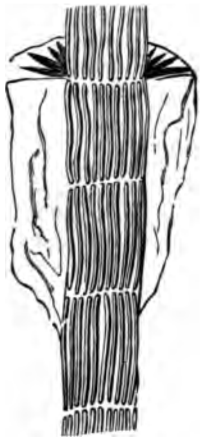
LIGN. 12.

Fig. 1.



Equisetum Lyelli.

Fig. 2.



Calamites radiata.

CALAMITES.

145. *Description.*—Stem articulated, regularly striated, the articulations naked, or studded with tubercles, and sometimes encircled by a stellated sheath, somewhat resembling the dentated, of the equisetums. The plants of this fossil genus, (none being recent,) are closely related to the horse-tails, but differ from them in having the stem uniformly striated and mostly in the absence of encircling sheaths, though a few have them. Some of this species have attained an enormous size, being from one to three feet in diameter, and from thirty to forty feet high. They abound in many of the coal formations, and constituted an important feature in the carboniferous epoch. They occur also in strata far more ancient, and some species appear to belong to the earliest terrestrial Flora of which any traces remain. In most instances, when speci-

How do the calamites differ from the equisetums?

mens are found lying in the same plane with the strata, they are pressed flat; but when occurring in a vertical position, as has been sometimes the case, they retain their cylindrical form. An outer crust, or pellicle of coal, generally surrounds the stem, but no remains of internal structure have been observed.

146. The stem figured, *Lign* 12, *Fig*. 2, has a stellate sheath at the upper joint, and shows the difference between this appendage and the dentated sheath of the Equiseta, as shown in the figure. It is the *Calamites radiata*, represented one half the natural size.

LIGN. 13.

Calamites nodosus.

In a few instances, the foliage of the Calamites has been preserved, a specimen of which is shown by *Lign.* 13. This is a remarkable example of the ancient Fossil Flora; and as a representation of the plants which once

covered the earth, may serve to elevate our ideas of the glory and beauty of our planet, before the surface was rèndered chaotic by the tremendous forces which acted upon it. It is the *Calamites nodosus*, from coal shale.

FILICES OR FERNS.

147. Having already given some account of the geography of the ferns, (84,) as well as their structure, (85,) we will only add, before entering on the description of individual species, that the tree ferns, may be recognized in the fossil state, by their cylindrical forms, without limbs, and the regular disposition and peculiar character of the scars (85,) left by the separation of the petioles. The leaves may be identified by the form of their segments, or lobes, which are disposed with remarkable regularity, and have a peculiar mode of subdivision; and especially by the delicacy, evenness, and peculiar distribution of the veins.

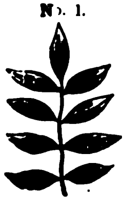
148. There are upwards of two thousand known species of living ferns at the present time, many of which have been discovered and named within a few years, and it is probable there may be as many more still unknown. Of fossil ferns, about one hundred and fifty species, all extinct, have been collected from the carboniferous strata. The arborescent ferns of the present day are almost exclusively confined to the equatorial regions, humidity and heat being the conditions most favorable to their development.

149. *Digression.*—There are necessarily a few botanical terms employed in the descriptions of the ferns, which those not conversant with that science will not be likely to understand, and which, indeed, as they relate to the forms of the plants, cannot be comprehended without the use of cuts. For the benefit and use of such, the following are introduced.

LEAVES.

150. With respect to forms, leaves are either simple or single, as that of the lily; or compound, as those of the rose. Compound leaves are divided into *pinnate*, *bipinnate*, &c., or *ternate* and *biternate*, &c. The following cuts will show these distinctions.

No. 1.



No. 2.

No. 1. A *pinnate*, or winged leaf. The petiole, or foot-stalk, has several leaflets on each side, growing in opposite pairs.

No. 2. A *bipinnate* leaf. In this the petiole is divided into several parts, each of which bears leaflets like the simple pinnate leaf.

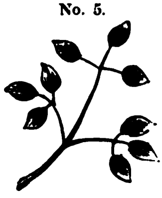
No. 3.

No. 4.

No. 3. A *tripinnate* leaf. The petiole is here divided into three parts, each of which are bipinnate.

No. 4. A *ternate* leaf. That is, the same foot-stalk bears three leaves.

No. 5.



No. 6.

No. 5. A *biternate* leaf. That is, the foot-stalk is divided into three parts, each of which bears a ternate leaf.

No. 6. A *triternate* leaf. That is, three times three-leaved.

Having made this digression, we now proceed; first, however, informing the reader, that the fern leaves are called *fronds*, and that the names of the genera are derived from *pteris*, fern, to which is prefixed some term indicative of its peculiar character, as *neuropteris*, nerved fern, &c.

151. Genus PACHYPTERIS, *thick fern*, *Lign.* 14. Frond pinnated, the leaflets entire, having a midrib, but without veins; contracted at the base, and lanceolate. The absence of veins, and the leaflets not being lobed, are the essential characters of this genus. The leaves are thick, an uncommon trait in this tribe. The species figured is the *Pachypteris lanceolata*, and is found in the inferior Oolite, (128.)

LIGN. 14.

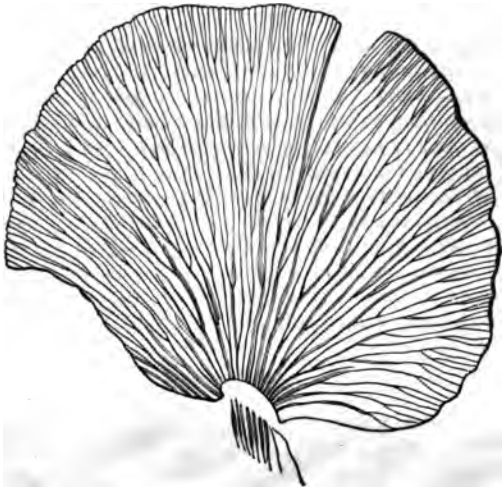
Thick fern.

152. Genus CYCLOPTERIS, *round fern*, *Lign.* 15. Frond simple and entire, and generally orbicular, or kidney-sha ped; veins numerous, equal and dichotomous, or forked, and radiating from the base. The essential distinction is the absence of a midrib or medial vein. Species, *trichomanoides*. Found in Oolite, (128.)

153. Genus ODONTOPTERIS, *toothed fern*, *Lign.* 16. Frond bipinnate, the leaflets adhering to the foot-stalks by the base, which is not contracted; veins equal, simple, dichotomous, arising from the rachis, or division of the foot-stalk; midrib none. In their general aspect, this genus resembles some South American osmunda. Five species are known, all of which belong to the most ancient coa strata. Species, *Schlotheimii*. From coal-shale, Saxony

What is the form of a pinnate leaf? What of bipinnate? A tripin nate? A ternate? A biternate?

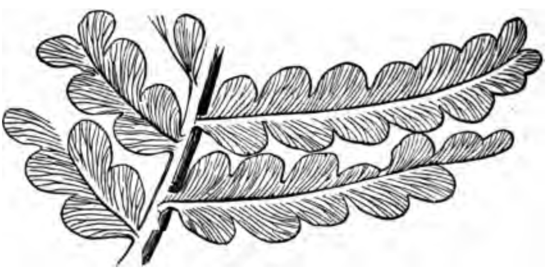
LIGN. 15.



Round fern.

154. Genus Anomopteris, *anomalous fern*, *Lign.* 17.—Frond deeply pinnated, leaflets very long, entire, linear; midrib distinct, and as long as the leaflet; veins simple, perpendicular to the median vein, and extending to the margin of the leaflet.

LIGN. 16.



Toothed fern.

Leaves of large size, and probably belonged to an arborescent fern. Species, *mougeotii*. From new red sandstone, (132.) A portion is magnified to show the fructification.

LIGN. 17.

Anomalous fern.

155. Genus PECOPTERIS, *embroidered fern*, *Lign*. 18. Frond once, twice, or thrice pinnated; leaflets adhering by the base to the rachis; traversed by a strong midrib, which reaches the apex; veins once or twice dichotomous; and nearly perpendicular to the median vein. The species here figured is once pinnated. It is the species *lonchitica*, and is from the coal-shale, France.

This genus embraces by far the greatest proportion of the ferns, which have contributed to the formation of coal in all countries. The originals of many species were undoubtedly arborescent, and attained a very large size. Some fronds have been found, which were four feet wide, and of proportionate length. More than one hundred species have been determined. The species have been found in America and England, as well as in France.

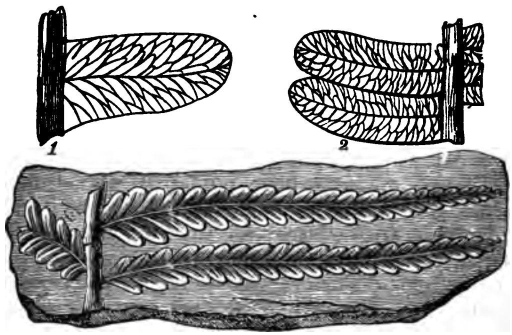
156. Genus LONCHOPTERIS, *spear-leafed fern*, *Lign*. 19. Leaves many times pinnated; leaflets more or less adherent to each other at the base, and traversed by a midrib; secondary veins reticulated. Only a small portion of the frond is here figured. Species, *Mantellii*. Found in the Wealden, (137.) This species seems to be a very deli-

LIGN. 18.

Embroidered fern.

cate plant; for although indications of its presence are very general throughout the fine micaceous grits, and even the clays of Wealden, a perfect leaf is of rare occurrence. The upper figures are magnified leaflets, to show the reticulations.

LIGN. 19.

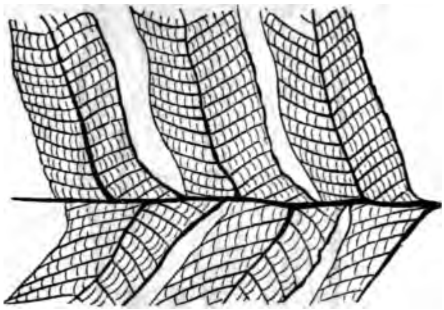


Spear-leafed fern.

157. Genus Clathropteris, *latticed fern*, *Lign.* 20. Frond deeply pinnatified, or cut into wings; leaflets elongated; midrib extending to the apex; veins simple, parallel, nearly perpendicular to the midrib, united by transverse bars, producing a quadrangular reticulation. Species, *meniscoides*. From the Wealden the original frond being one and a half feet long.

This genus was instituted by M. Brongniart, to include some fronds from the shale of Hoer, in Scamia, which resemble in structure, the foliage of the recent *Polypodium quercifolium* a native of the East Indies.

LIGN. 20



Latticed fern.

ARBORESCENT FERN STEMS.

158. The fronds of a great variety of ferns, as already stated, are every where to be found in coal fields; but an undoubted stem of any of this family is very rare. A few fossil stems, however, having all the characters of recent species, have been found, and are arranged under the following genus:

159. Genus Caulopteris, *fern stem*, *Lign.* 21. Stem not channeled, marked with discoidal oblong or ovate scars, arranged longitudinally; vascular cicatrices numerous. Species, *macrodiscus*. From the coal fields.

The specimen figured is from the coal, and resembles the trunks of the living fern trees in its proportions, and in the number, disposition, and size of the scars of the leaf-stalks; but these markings differ from the recent, in the more lanceolate form and pointed terminations, and in their peculiarly striated surface.

SIGILLARIA.

160. *Name* from *Sigillum*, a seal, which alludes to the regular, and often beautiful, imprints on the stem.

What is said of the variety of fossil fern stems?

LIGN. 21.

Fern stem.

Among the most common, yet striking objects, says Mr. Mantell, that arrest the attention of a person who visits a coal mine for the first time, and examines the numerous vegetable relics that are profusely dispersed among the heaps of slate, coal and shale, are long flat slabs, with their surfaces longitudinally fluted, and uniformly ornamented with rows of deeply imprinted symmetrical figures; these are disposed with such perfect regularity, that the specimens are often supposed to be engraved stones, instead of natural productions. These fossils are the remains of the epidermis, rind or bark of the stems of gigantic trees; the regular imprints on the surface being the scars left by the separation of the leaf-stalks, as in the arborescent ferns just examined. The sigillaria are generally found lying in the horizontal position, and flattened by the superincumbent pressure; but a remarkable instance in which fern stems were found standing upright, with their roots in the soil, apparently in the position in which they grew, was brought to light near Manchester, England, during the excavations for a

What does the name Sigillaria mean? What is the appearance of a Sigillaria stem?

railway. Their roots are branched, and spread out in the bed of impure coal in which they are implanted. The largest tree is eleven feet high and seven and a half feet in circumference at the base; the others are smaller. All seem to have been broken off by violence, though no traces of their upper trunks or branches have been detected. So interesting has been this discovery, that the trees have been carefully preserved in their places, and plaster casts taken of them on a small scale, for sale to the curious.

161. *Size of the Sigillaria.*—The stems of the Sigillaria vary in size, from a few inches to five feet in diameter, and in length, from five to sixty feet; they gradually taper from the base to the summit. It appears that this tree, like the oak and chestnut, grew in every part of the world; for besides being found in many parts of Europe, and in New Zealand, the most remarkable locality yet known is on this side the Atlantic. On the southern shore of the Bay of Fundy, in Nova Scotia, where the cliffs are about two hundred feet high, and composed of carboniferous strata, there are numerous trees, probably Sigillaria, standing in ten rows, one above the other, indicating, observes Mr. Lyell, repeated subsidences of the land, so as to allow the growth of ten successive forests.

162. *Class of the Sigillaria.*—It has been difficult to decide, with respect to the structure of this tree, on account of the destruction of its interior; in most instances, the bark only showing signs of vegetation, all other parts being solid limestone. In a few instances, however, specimens have shown medullary rays, and a coniferous structure, which makes it an exogenous or dicotyledonous tree. Of the Sigillaria, about forty species are known.

163. Sigillaria Saulii, *Lign.* 22. From coal near Manchester, England. The full description already given of this genus, makes it unnecessary to be more particular with respect to this species. The carbonized bark, in large specimens, is often an inch thick, and being extremely brittle, flakes off at the least touch, leaving the inner surface exposed, the coal remaining only in the deep furrows and pits. The difference thus made is shown by the

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What is said of those uncovered near Manchester? What is said of the size of the Sigillaria? To what class does this tree belong?

figure, where the scars of the leaves, whence the tree received its name, are left with the bark, while the dark portion is the inner surface, exposed by the removal of the outer crust or bark

LIGN. 22.

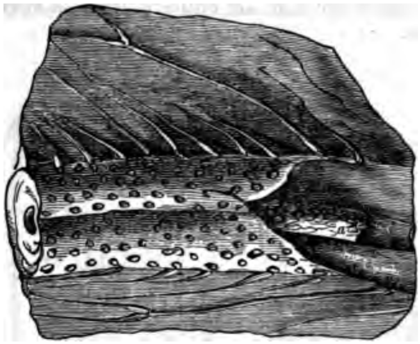
Sigillaria.

STIGMARIA.

164. *Lign*. 23. Equally common with the Sigillaria, in every coal mine, is the *spotted stem*, or *Stigmaria*. These are cylindrical bodies, varying from a few inches to several feet in length, and four or five inches in diameter. Their surfaces are covered with numerous pits, or areola, which are disposed in quincunx order. These markings are oval, or circular, and have a small elevation, or tubercle, in the middle of each depression. When broken across, a small cylindrical body, or core, is found to extend longitudinally through the stem, like a medullary column. This core seldom occupies the centre, or axis, being situated near one side, and opposite to a groove, or channel, on the outer surface. This internal body is often loose, and may readily be removed; its surface is covered with interrupted, irregular longitudinal ridges, which leave corresponding depressions on the walls of the cavity in which it was contained.

The figure represents a fragment with the characters above described. It is the *Stigmaria ficoides*. From the

LIGN. 23.



Stigmaria.

coal of Derbyshire. It is a portion of a stem, with some of the processes formerly considered leaves, extending into the surrounding clay. The internal body is seen at *a*, also the corresponding groove on the portion of external surface that remains.

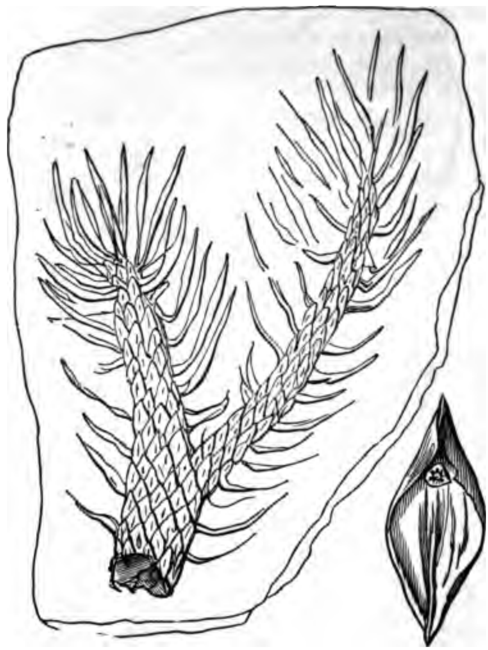
165. No organic relic found in the coal mines has excited more curiosity and scientific attention than this. Of course it was considered the stem of a tree, perhaps allied to the sigillaria, and several learned memoirs, with illustrations, were produced; some showing that it was an exogenæ, while others contended that it was an aquatic plant. Meantime, M. Brongniart, after a careful examination of the best specimens that could be found, came to the conclusion that it was not an aquatic, but the roots of the sigillaria, and it appears more recently that some uncommonly good specimens, found near Liverpool, have confirmed this decision.

LEPIDODENDRON.

166. *Scaly-tree.*—Stems cylindrical, covered towards their extremities with simple linear or lanceolate leaves, which are attached to elevated rhomboidal spots or papillæ; papillæ marked on the upper part with large transverse, triangular scars; lower part of the stem destitute of leaves. *Lign.* 24 represents a branch of this tree, from

the coal-shale, Newcastle. The small figure is one of the scars left by the separation of a leaf of the natural size. It will be observed that the entire branch is covered with such scars.

LIGN. 24.



Scaly-tree.

The scaly-tree is very abundant in most English coal mines, where some have been found nearly entire, from their roots to their upper branches. They were of vast size, one specimen being forty feet long and thirteen feet in circumference at the base, divided towards the summit into fifteen or twenty branches. The foliage of these trees consisted of simple linear leaves, spirally arranged around the stem, and appear to have been shed from the attachment by age.

167. In their structure, external configuration, mode of ramification, and disposition of the leaves, these trees accord so closely with the *Lycopodiums*, that notwithstanding the disparity in size, M. Brongniart asserts that they must be considered as gigantic arborescent club-mosses. The lycopodiums of the present day, most of them, trail on the ground, and are well known as "Christmas greens," to make wreaths for the decoration of churches, &c. They are from a few inches to a foot or two high.

FOSSIL SEEDS.

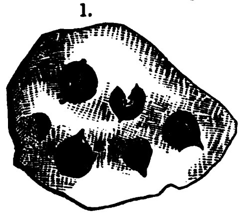
168. In many instances the seeds of extinct plants have been found, of course in a petrified state, but it is difficult to determine to what vegetables they belong, being always detached, and usually found by themselves. Nothing remains by which their structure can be determined, their forms only being preserved.

CARDIOCARPON.

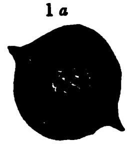
169. *Heart-shaped seeds.—Lign.* 25. The seed-vessels here represented are found in sandstone and coal-shale, in the midst of fossil plants, but grouped together in various numbers, from five to twenty. They evidently grew

LIGN. 25.

1.



1 *a*



Fossil seeds.

together, forming what are called twin seeds. 1 *a* is magnified from the group 1, in order to show the surface by which it was attached to its other half. Nothing is known of the trees to which these seeds belonged.

What is said of fossil seeds?

FOSSIL CONIFERÆ.

170. We have already described this family (77) and illustrated its structure (*Ling.* 4 *and* 5); but as remains of cone-bearing trees are found in geological strata in nearly every part of the world, and often in such quantities and of such sizes as to excite peculiar attention, the subject seems to claim some additional notice.

Most of the wood of this genus found in the British mines appears to have been of the species *araucaria*, (80,) of which the celebrated Norfolk pine, one of the largest trees now growing, is a member. But one of the most extraordinary and interesting assemblages of these trees is that in the Isle of Portland, England, where an entire forest of pines appears to have been transformed into stone on the very spot on which it grew; the Cycadeæ still shooting up, as it were, between the trunks and roots of the trees, though changed into flint, extending into the bed of mold from which they originally derived their support.

In the sands of the desert of Sahara in Egypt; among the bones of the mammalia near the Himalaya mountains, and in the tertiary deposits of Virginia, drifted coniferous wood, associated with Cycadeæ, have been discovered. Trees of this family, of a highly interesting character, are also found in various parts of Australia and Van Dieman's Land. In the latter country these trees of stone are described as standing erect to the height of several feet, in a bed of arid sand, apparently in the places where they grew; their petrified stems and branches being scattered around them. So entirely do these trees of stone preserve their natural woody appearance, that one of the emigrants relates, among the extraordinary sights he witnessed in New Holland, the burning of trees to manure the ground.

A still more extraordinary forest of petrified stumps is described by Rev. Mr. Clark, as existing in Australia. Stumps of fossilized trees are seen projecting out of the ground, presenting the appearance of a forest in which the trees are all cut down to the same level. At the distance of some yards from the shore, a reef is formed by vertical rows of the petrified stems, which project above the surface

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What is said of the distribution of fossil pines? What is said of the petrified forest of Australia? How is this accounted for?

of the water. Those on the land stand generally about three or four feet above the surface, and are from two to six feet in diameter. The wood is silicified, and veins of chalcedony traverse the substance of the trunks between the concentric rings and medullary rays. In several examples, from sixty to one hundred and twenty annual rings were observable. As to any hypothesis of the means by which this forest was petrified, no remarks are offered; but it is certain, that these trees must have been in a different situation, when this was effected; for the atmosphere, or the waters of the ocean, never produce such changes. They must therefore have, at some period, been under the earth, perhaps by the subsidence of the ground on which they stood, and after being petrified, raised by volcanic force to their present situation.

FOSSIL PALMS.

171. This family at the present day are exclusively natives of intertropical climates, and are remarkable for their elegant forms and striking aspects. The Date, Cocoa-nut, Talipot, Fan-palm and many others, are members of this large and magnificent genus. They have a single cylindrical stem, sometimes growing to the height of a large ship's mast, with a top spreading out like a canopy, and sometimes consisting of leaves twenty feet long, and nearly as many wide. The trunks and even leaves of this family are found in the fossil state in various parts of the world. Dr. Buckland states, that stems of palms, beautifully silicified, occur in the tertiary deposits of Hungary. They are also found in France, Italy and the West Indies. In England they occur in the oolite formations and in coal fields. Nor is the United States without her share of these tropical relics, a group of fossil palm-trees having been discovered and described by Dr. Owen, of New Harmony, in the state of Indiana. It occurs in one of the upper members of the Illinois coal-fields, where from twenty to thirty trees were found, with their main roots attached and ramifying in the clay, and their stems in the coal and sandstone above, as if submerged on the spot where they originally grew. A carbonaceous

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What is said of the recent palms? What is said of the distribution of fossil palms? What locality is mentioned in this country?

crust envelopes the trunks, which are covered with lozenge-shaped scars, having a transverse direction, and presenting a diversity of figures in the attachment of the petioles, which indicates at least three species of this genus. *Silliman's Journal*, 1843.

Change of Climate.—"It is not surprising," says Dr. Buckland, "to find the remains of palms in warm latitudes, where this family are now indigenous, as in Antigua and India; but their occurrence in the tertiary formations of Europe, (and we may say of North America also,) associated with the remains of crocodiles and tortoises, and with marine shells, nearly allied to forms which are at present found only in seas of a warm temperature, seems to indicate that the climate of Europe, during the tertiary period, was warmer than it is at present."

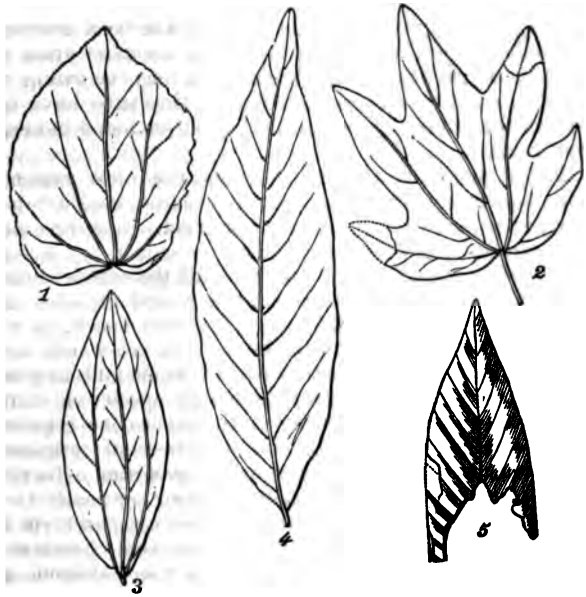
FOSSIL LEAVES.

172. Palm-leaves occur in France, Switzerland and Tyrol, but differ materially from any living species. These leaves are said to be too well preserved to have endured transportation by water from a distant region, and must therefore be referred to extinct species, which in the tertiary period were indigenous in Europe.

Foliage of Dicotyledonous plants.—These are of frequent occurrence in the tertiary marls and limestones of England, and are sometimes abundant, and in good preservation. But more perfect examples occur in the tertiary strata near Pavia in Italy. These leaves belong to several genera of ligneous dicotyledons, and most of them to species which still grow in the vicinity. In some cases the substance of the leaf is changed into carbon, the structure being well preserved; but, in general, sharp and well-defined imprints only are left on the stone, being exact copies of the outlines and larger veins of the originals. They are found in a gypseous marl, of a cream color; and from their perfect state, it is inferred that they were enveloped in the soft matrix, where they are found, soon after their fall, and were preserved by the rapid hardening of the strata. *Lign.* 26. It will be obvious from the figures that all these leaves are of species now growing. No. 1, Poplar, *Populus græca.* 2, Maple, *Acer.* 3,

What indications with respect to climate are inferred from this fact?

LIGN. 26.



Exogenous leaves.

Water-spike, *Potamogeton.* 4, Willow, *Salix.* 5, Chestnut, *Æsculus.* From what has been remarked heretofore, it is an exceedingly rare occurrence to detect fossil remains, either of animals or plants, of the *species* now living, though *genera* of the ancient and present Flora are not uncommon.

GENERAL REMARKS ON FOSSIL VEGETABLES.

173. The design of this book will not allow of a more extended account of fossil plants ; but before leaving the subject, we shall make a few remarks on the foregoing synopsis, and especially with respect to the geological periods of the ancient or Fossil Flora.

What number of species of fossil plants are known?

It appears from the catalogue of fossil vegetables, published by Mr. Morris in 1843, that in the British strata alone there had been discovered above six hundred species. Among these, only two of the *grasses* had been detected, these being of the genus *Poa*, a very common grass in most parts of the world. Possibly it may be owing to their diminutive size that so few of this tribe have occurred, though many ferns, little larger, are found in every coal mine.

From the data hitherto obtained the most eminent botanists, Sternberg, Brongniart and Lindly, consider that the Floras of the ancient world would constitute three distinct periods or epochs.

First Epoch.—The first comprehends the earliest strata in which traces of vegetables appear, and includes the Carboniferous, (131.) The plants of this epoch, as we have already shown, consist of fuci, or sea-weeds, and other cellular tribes; ferns of various kinds and in great abundance; coniferous trees, related to species in warm climates; of palms and other monocotyledons; gigantic lycopodia, or club-mosses; and large trees of unknown tribes, as Sigillaria and Stigmaria, in profusion. In this Flora the tree ferns predominate, constituting nearly two-thirds of the whole known species, and the general type of the vegetation is analogous to that of tropical climates.

Second Epoch.—This extends from the Saliferous or New Red, (130,) to the Chalk inclusive, and is characterized by the appearance of many species of the Cycadéæ, Zamiæ, and Coniferæ, while the proportions of the ferns are much less than in the preceding period, and the Lycopodiums, and Calamites of the Carboniferous strata, are absent. A Flora of these remains would be analogous to that of the coasts of New-Holland and the Cape of Good Hope.

Third Epoch.—The third epoch is that of the Tertiary, (125,) in which the Dicotyledonous tribes appear in great numbers: the Cycadeæ are very rare; the ferns are comparatively few; and the Coniferæ more numerous. Palms and intertropical plants are found associated with the existing European forest trees, as the elm, willow,

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What are the three epochs of fossil Botany? What plants form the Flora of the first epoch? What of the second? What of the third?

and chestnut, presenting in short the general features of a Flora of the present day.

174. *Absence of the grasses.*—But we must not omit to notice a remarkable feature in the Floras of the secondary strata, namely the almost entire absence of the *grasses*, or *gramineæ*, which form so large a proportion of existing plants. It has been suggested, that the greater or lesser durability of the foliage of certain vegetables may have occasioned their presence or absence in the carboniferous deposits, and experiments have been instituted with the view of determining this question, as already stated, (100.) But though it was found that, when the foliage of various families of plants was subjected to long maceration, the leaves of the dicotyledons and grasses disappeared, while the ferns and cycadeæ remained; yet this experiment does not meet the exigences of the case. We have no evidence to show that the fossil leaves were ever placed in similar conditions; on the contrary, there is reason to conclude that they were imbedded under circumstances that arrested the usual progress of decomposition, prevented the escape of the hydrogen and other gaseous elements, and gave rise to the bituminous fermentation by which they were converted into lignite and coal. To these objections to Dr. Lindly's experiment, made by Mr. Mantell, we will add from Count Sternberg, that there is no probability that fossil plants were submerged in pure water, as in the experiment; but, on the contrary, it is pretty certain that whether covered suddenly with earth, or not, they were at least thrown into water charged with mud, and perhaps also with lime, and that either might have been the means of their preservation.

What formations mark the periods of these vegetable epochs?

PART II.

PALÆONTOLOGY;

OR,

THE SCIENCE OF FOSSIL ANIMAL REMAINS.

175. *Retrospect.*—HAVING in our Preliminary Remarks, and in Part I., given a general history of the fossil animal kingdom, embracing a table showing the strata chiefly composed of animal remains (13); having also shown that similar remains exist in similar strata, (30,) that the lowest orders are found in the deepest formations, (33,) that most of these animals are of extinct species, (31,)that shells are the most common remains, (35,) that fossils are chiefly accumulated by the action of water (42); also, the conditions in which animal fossils are found, (44,) hints for collecting fossil bones (47) and mending broken bones; having thus prepared the way, we shall now proceed to describe and illustrate families and individual species of extinct animals, to the extent of our limits, selecting such as we believe will be most interesting and instructive to our readers.

Our guide in what follows will be chiefly that beautiful and interesting work, the *Medals of Creation*, from which our lignographs, illustrating fossil plants, shells and reptiles, are mostly selected.

CHAPTER XIV.

ARRANGEMENT OF ANIMAL REMAINS.

176. THE recent, or living species of the animal kingdom, exceed one hundred thousand. This includes all the living existences embraced in the natural science of *Zoology*, as the Insects, Fishes, Shells, Birds, Worms and

Beasts of the field. The animals known in the fossil state are estimated at less than ten thousand. These embrace all the different classes or families named above, and so universal has been the destruction or burial of the classes and orders, during the turmoil which the ancient earth has suffered, that most of the classes and families, and many of the genera now known, are represented by their fossil analogues, disinterred from the crust of the earth; and by the perseverance and ingenuity of man, described, classed and named, so as to be known and recognized by those conversant with the subject.

177. We know not, however, but some whole families, of which we know nothing, have been entirely destroyed by the catastrophe of the former world; nor can we say, at present, but representatives of all the living species now existing will ultimately be discovered in the fossil state; for as yet we know comparatively very little of what the earth contains. It is certain, however, that some families of colossal animals, both of the land and sea, have become entirely extinct, and of which no examples of even their orders are now living; such as the Plesiosaurus, the Megatherium and others.

178. *Order of Arrangement.*—Our illustrations and descriptions will commence with the minutest organic existences, and proceed in an ascending scale to the more perfect animals, in accordance with the following zoological order.

ARRANGEMENT OF FOSSIL ANIMALS.

I. INFUSORIA, Animalcules, *little animals.*

This section embraces, not only the remains of Animalcules, but also the relics of other minute beings associated with them, and which cannot be investigated without the aid of the microscope. These are called *Infusoria*, because the infusion of almost any vegetable, as a handful of leaves in a cup of water in warm weather, brings them into action. Stagnant water, into which leaves have fallen, always contains them.

II. ZOOPHYTES, *Animal plants*, including—

1. AMORPHOZOA, *irregular forms*, as the Sponges.
2. POLYPARIA, *Many footed*, as the Coral animals.

What is the number of recent animal species? What is the number of fossil species? Is it certain we shall not discover examples of all the recent species? Why?

III. ECHINODERMA, *Spiny-skinned*, including—

1. CRINOIDEA, Lily-shaped animals.
2. ASTERIA, Star-fishes.
3. ECHINIDA, Sea-urchins.

IV MOLLUSCA, *Soft animals*, including—

1. BIVALVES, as the Oyster and Clam.
2. UNIVALVES, as the Periwinkle and Snail.
3. CHAMBERED SHELLS, as the Nautilus, including the testacea, and those destitute of shells, as the Sepia or Cuttlefish.

V ARTICULATA, *Jointed animals*, including—

1. CIRRIPEDIA, *Curly-footed*, as the Barnacle.
2. ANNULATA, *composed of rings*, as the earth-worm.
3. INSECTA, *Insects*, as Wasps and Hornets.
4. CRUSTACEA, *Crusty-skinned*, as Lobsters and Crabs.

VI. PISCES, *Fishes.*

VII. REPTILIA, *Reptiles.*

VIII. AVES, *Birds.*

IX. MAMMALIA, *Milk-givers.*

The above is Mr. Mantell's arrangement, adapted to Fossil Zoology, and is founded on Prof. Owen's more extensive Classification of the Animal Kingdom.

CHAPTER XV.

INFUSORIA, AND OTHER MICROSCOPIC ANIMALCULES.

179. THE philosophers of the present day, and especially M. Ehrenberg, have forced us to believe the marvelous fact, that whole mountains are chiefly formed by the mineralized remains of a class of beings, so minute that they cannot be distinguished without the aid of the microscope. In our own country, Professor Bailey, of West Point, by the same means, has not only confirmed the minute observations of Professor Ehrenberg, but has found that other minerals, not suspected by the former philosopher, are also composed

What are Infusoria? Zoophytes? What Echinoderma? What Mollusca? What bivalves, univalves, &c.? What Articulata? What crustacea, &c.? What is said of the remains of Infusoria?

of remains of these more than tiny insects. This is not the least of the wonders which the sciences of the present day have brought to light; and it is now not only well understood that formations of limestone and chalk are the works of infusoria, but also that they are contained in the hardest stones, as flint, chalcedony, opal and emery.

180. This interesting field of research will no doubt lead to discoveries and results little imagined by even the more sanguine of the present day. At present, says Dr. Mantell, this branch of palæontology is in its infancy, and it offers to the young student an inexhaustible and most inviting department of scientific investigation. It possesses, too, this great advantage over many other subjects, that it is within the reach of every one; for it can be pursued at home and the materials for its investigation are ever at hand.

LIVING INFUSORIA.

181. That the reader may have an idea of the forms of the living animals whose mineralized remains we are about to investigate, accurate figures of several recent species, allied to those often found fossil, are given. Their forms so entirely depend on their durable cases, or framework, that the latter may easily be recognized, even when the soft parts have entirely disappeared. These shells or cases, in some families, are calcareous, and in others consist of pure, colorless, transparent silex, or flint. But many have a naked and flexible skin, and these of course are not preserved as fossils; those having an armor or shield, constructed of silex, lime, or iron, alone leaving enduring remains of their existence.

XANTHIDIUM.

182. The carapace, or case, of this genus of animalcules, consists of a hollow silicious globe, in which the body is contained; this is beset with tubular spines, that probably contained tentacula, or arms, but these have not been observed. Like most of the infusoria, the *Xanthidia* increase by self-division; hence the double appearance in the figures, all of which represent individuals in the

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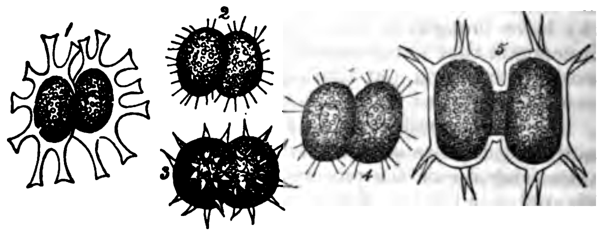
Is it the animals themselves, or the cases they made, which have been detected? What are the shells made of?

LIGN. 27.



Infusoria.

progress of separation. They are not lively, progressive animals, but are commonly stationary, perhaps at work building their cases, of which to form mountains. The name *Xanthidium* comes from the Greek *xanthic*, yellowish, the color of the animal. A line being the $\frac{1}{12}$ of an inch, the student may gain some idea of the dimensions of the above species.

No. 1. *Xanthidium furcatum*, $\frac{1}{24}$ of a line in diameter. 2. *X. hirsutum*, $\frac{1}{36}$ of do. 3. *X. aculeatum*, $\frac{1}{24}$ do. 4. *X. fasciculatum*, $\frac{1}{24}$ do. 5. A variety of the *fasciculatum*.

The above, being of a globular form, it may be well to remark, that this is rarely the form of other species, these little beings assuming all sorts of shapes, linear, triangular, elliptical, tree-like, bottle-shaped, crossed-jointed, &c., while some are so entirely amorphous, as to be of no shape that words can express.

183. *Dr. Bailey's account.*—Professor Bailey, of West Point, says, that the fresh-water infusoria, *Meridion vernale*, is seen in immense quantities in the mountain brooks around West Point, the bottoms of which are covered in the first warm days of spring with a ferruginous-colored mucous matter, about a quarter of an inch thick, which, on examination by the microscope, proves to be filled with millions and millions of these exquisitely beautiful silicious bodies. Every submerged stone, twig, and spear of grass, is enveloped by them; and the waving, plume-like appearance of a filamentous body, covered in this manner, is often extremely elegant. Alcohol completely dissolves

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What idea can you give of the sizes of infusoria? What says Dr. Bailey on this subject?

the endochroma (soft coloring matter) of this species, and the frustrules (shields or cases) are left as colorless as glass, and resist the action of fire.

184. The field for infusorial investigation appears to be endless; almost every section of country, and sometimes every lump of earth or stone, affording new species or varieties. Prof. Bailey, from a specimen of earthy matter, of a whitish color, from Oregon, has discovered half a dozen new species. From a specimen of Tripoli from Bermuda, (a hard stone used for polishing metals,) sent M. Ehrenberg, by Prof. Bailey, that minute philosopher returns for answer that he had discovered, in the specimen sent, one hundred and thirty-eight species, including nine new genera, and fifty-eight new species. *Silliman's Journal*, 1843. From such accounts, the student in this new science may derive the satisfactory inference, that if he pursues the subject, he can scarcely fail to detect a sufficient number of new genera, or species, to immortalize his own name and those of all his friends. Indeed, we know not where philosophers are to find titles for all the species they are likely to discover, since a single inquirer has already published in *Silliman's Journal*, a list of two hundred and fifty Infusoria from three localities, with the names of the genera and species affixed. It is, however, not to be expected that all inquirers will have the science, zeal, and industry of Prof. Bailey, who, we believe, is only excelled in the knowledge of this subject by the eminent Ehrenberg, of Berlin, who first directed the attention of science to this investigation. Besides the more solid materials in which these animals are found, the yellow ocherous scum, observable in ponds, ditches, and stagnant pools, is an aggregation of animalcules, whose shells are ferruginous, and which are of such extreme minuteness, that one cubic inch must contain at least a billion of their cases or skeletons.

FOSSIL INFUSORIA.

185. From this notice of a few recent forms of infusoria, we proceed to the investigation, not only of the fossil remains of this class, but also to other minute animal organisms with which they are associated; and being

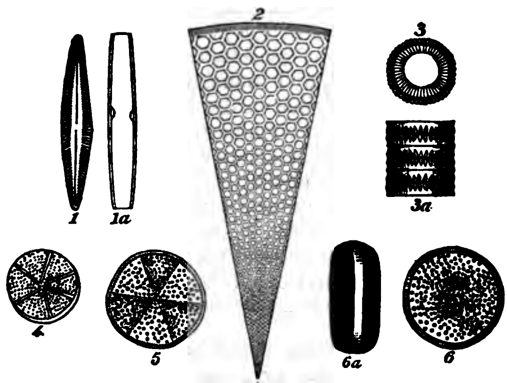
What number of infusoria did Ehrenberg find in a specimen of Tripoli? What is said of Prof. Bailey's discoveries on this subject?

invisible to the naked eye, will be conveniently examined in this place. These are the *Polythalamia*, (*many-chambered shells*,) and the *Foraminifera*, (*covered with pores*.)

In peat bogs and swamps, masses of a whitish paste or sand may often be observed; also, on the borders of stagnant pools, after being partly dried by the sun, there commonly remains, in the dark, hardened mud, grains of white sand. In either case, if this sand be placed under the microscope, it will be found to consist of the remains of infusoria, of many forms and species.

186. *Infusorial Marl of Richmond.*—The town of Richmond, in Virginia, is built on strata of silicious marls, of considerable extent and thickness. This formation Prof. Rogers refers to the older tertiary period. It occupies a wide, sandy and sterile district, rendered so by its silicious surface, there being little nourishment for vegetation, except what is supplied by art. This sandy soil Prof. Bailey has shown to consist of the remains of several species of infusoria, represented by *Lign.* 28, highly magnified.

LIGN. 28.



Infusoria.

Fig. 1. *Navicula.* 1*a*, a side view of the same. 2. *Coscinodiscus radiatus*, a portion of the circular shield. 3.

What is said of the infusoria in the marl of Richmond?

Gaillonella sulcata. The upper figure shows the face of one of the joints, or animalcules, and 3*a*, three of the same united. 4. *Actinocyclus.* 5. Another species of the same. 6. *Coscinodiscus.* 6*a*, front view.

The most remarkable and curious forms are saucer-shaped shells or disks, having their surfaces elaborately ornamented with hexagonal spots, disposed in curves, presenting some resemblance to the engine-turned case of a watch. No. 2 is a small section of such a shell, very highly magnified. These cases or disks vary in size, from $\frac{1}{180}$ to $\frac{1}{1000}$ of an inch in diameter.

When a few grains of this marl are prepared, and mounted on a glass, almost all these varieties will be manifest, so largely is this earth composed of the skeletons of these animals. In fact, very few inorganic particles are mixed with these organic remains.

ANIMALCULES IN CHALK.

187. M. Ehrenberg has demonstrated that a cubic inch of chalk may contain at least one million of well-preserved animalcules and shells. The larger species of these may be obtained by brushing the chalk into cold water; but the microscopic forms remain a long time suspended in the water, and can only be obtained by a peculiar process.

"Chalk, therefore," says Mr. Mantell, "must be regarded as an aggregate of exceedingly minute organisms, and of inorganic particles. The soft yellow chalk of the north of Europe, is composed of about one-half its bulk of fossil bodies; but in that of the south of Europe, the organic remains largely predominate."

The most abundant animal remains in chalk, are two kinds of *Polythalamia*, called *Rotalia* and *Textularia.* It must not, however, be understood that these remains can be seen in abundance, even with a good microscope, without careful preparation, and considerable experience in the use of the instrument; for the observer will sometimes see millions of atoms with few entire animal remains.

188. The genus Polythalamia, (*many-chambered,*) contains a considerable number of species; but in the following Lignograph, we have followed our guide in inserting several of the most curious and interesting figures among

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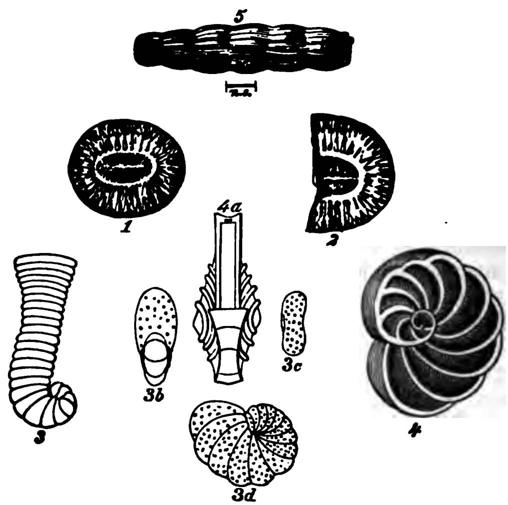
How large are the shells of these beings? How many organic remains are found in a square inch of chalk?

the vast numbers which have been observed, without regard to genera. They are from chalk, and greatly magnified. *Lign* 29.

No. 1. *Campilodiscus*, a *perfect shield.* 2. Part of another of the same kind. 3. *Lituola nautilidæ;* 3*a*, side view of the same; 3*b*, the last cell in 3*a*; 3*c*, side view of a young shell before it is produced. 4. *Flabellina baudonia;* 4*a*, the same individual seen in profile, showing the double spiral structure. 5. *Nodosaria.* The line below indicates the natural size.

LIGN. 29.



Polythalamia.

Lituola, *crosier-like shell.* This in its young state is of a discoidal involute form, as shown above, 3*b*, 3*d;* but with age it becomes produced or unfolded, and assumes the form of a crosier, as seen 3*a*.

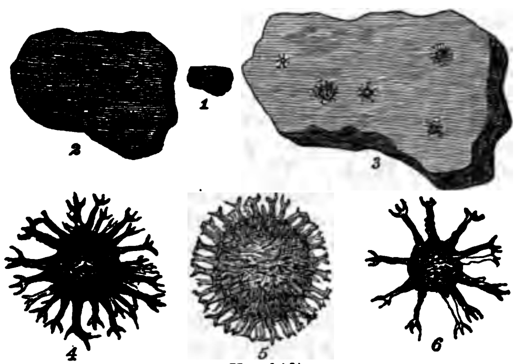
Flabellina, *fan-shaped.* This occurs in the chalk of France and England. When viewed in different aspects, this shell presents quite dissimilar forms. Seen in profile, 4*a*, it is somewhat fan-shaped; but viewed laterally, it presents a spiral and chambered structure, as at 4, *Lign.*

29. The large coralline species, fig. 5, is often associated with the above

FOSSIL XANTHIDIA.

We have already represented several living species of this family at *Lign.* 27. They are also found in the fossil state in abundance, both in chalk and flint, and are among the interesting and elegant forms found among these minute beings. When the animals die, their soft parts rapidly decompose, and their silicious cases remain, appearing as spheroidal or globular bodies, beset with spines. "One of the most interesting groups of Xanthidia," says Mr. Mantell, "was discovered by my son, Reginald Nevill Mantell, in a fragment chipped off a flint pebble, by a smart blow of a hammer; and I will describe the mode by which these bodies were detected, as it gives a good practical lesson for the young investigator:

LIGN. 30.



Xanthidia.

"These bodies vary from $\frac{1}{300}$ to $\frac{1}{500}$ of an inch in diameter. The chip of flint, of the natural size, is represented in *Lign.* 30, fig. 1. It was immersed in oil of turpentine for a short time, and then placed on a piece of glass, and examined with a moderate power by transmitted light, the turpentine having rendered the translucent flint nearly as transparent as glass; this appearance is shown by fig. 2. The half-inch object-glass was then employed, and fig. 3

is the result. The quarter-inch object-glass, and a corresponding eye-piece, were then substituted, and by the adoption of a camera lucida, figs. 4, 5 and 6 were delineated. Fig. 5 proved to be a new species, and has therefore been named after the discoverer, *Xanthidium Reginaldi.* Fig. 4, *X. ramosum.* Fig. 6. a variety of *X. ramosum*"

MICROSCOPIC EXAMINATIONS OF CHALK AND FLINT.

189. The following method is that of Ehrenberg: Place a drop of water on a plate of thin glass, and put into it as much scraped chalk as will cover the point of a knife, spreading it out, and leaving it to rest for a few seconds; then withdraw the finest particles, which are suspended in the water, together with most of the liquid, and let the remainder become perfectly dry. Cover this dried spot of chalk with Canada balsam, (the turpentine of *Abies balsamea,*) and hold the plate of glass over the flame of a lamp, until the balsam becomes slightly fluid, but without froth or air-bubbles; it should be maintained in this position, the glass being kept as hot as the fingers will bear, for a few minutes, until the balsam is found to have thoroughly permeated the substance to be examined. It is preferable to place a piece of thin glass upon the balsam, and gently press it down, and allow it to remain. (Glass for this purpose may be purchased in London, only $\frac{1}{100}$ of an inch thick.) The best flattened crown-glass should be used to place the chalk or other objects on. It is convenient to have the slips of glass of one size, or the specimens will require different boxes for their reception; three inches by one inch, is that usually employed. These objects require to be viewed with a magnifying power three hundred times linear, that is, in diameter; and if the process has been properly conducted, it will be seen that the chalk is chiefly composed of well-preserved organisms. In these preparations, all the cells of the Polythalamia appear at first black, with a white central spot which is caused by the air contained in those cavities; for air bubbles always appear under water as black annular bodies; but by degrees, the balsam penetrates into all the single cells, the black rings of the air vesicles disappear, and the structure of the originals is beautifully displayed. M. C. 245.

CHAPTER XVI.

FOSSIL POLYPARIA.

190. The living forms which come under this order, some of which are of the very lowest creations of animated beings, are almost innumerable. The term Polyparia, signifying *animal plants*, indicates that these are the links which connect the animal and the vegetable kingdoms. Some of the tribes, as the hydra, have the power of moving in the water by elongating and contracting their bodies and tentacula; while others, as the sponges and corals, are fixed, and have not the power of locomotion. (A more particular account of these animals is contained in the first part of the author's Physiology.) The hydras, being soft animals, and building no silicious habitations, have no fossil remains; but the sponges and corals are not unfrequently found petrified. One species, in particular, of the former, of large size, being twelve or fourteen inches in length, and spreading into numerous branches, occurs in this state. Such masses are called *Spongites*, that is, *sponge stones*, and many of them belong to species now growing.

The coral polyparia are groups of polypes, permanently united at the base, and arranged side by side, each having an individual existence. A common support or skeleton is secreted by the united action of the group, and which varies in its consistence from a gelatinous, or horny material, to a calcareous frame-work, that remains when the animals or polypi die, and their soft parts decompose. The basis or skeleton of these groups is termed *polypidom*, (*polype-house*,) and those left of a stony hardness, are familiarly known as *corals;* the name, therefore, refers to the durable remains of the polypi, and not to the animals themselves.

191. It may be well to notice here a prevailing error, in regard to the mode in which the substances called corals are produced. It is generally supposed that corals,

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What does polyparia signify? Of what order of creation are they What are the coral polyparia?

particularly those covered by stars and cells, have been constructed by the polypes, in the same manner as the honey-comb is by the bee; and the expressions, often employed by naturalists, of "the coral animalcules building up their rocky habitations," and "constructing their cells in a particular manner," have contributed to perpetuate the error. But the cases are in no respect similar; the bee, under the guidance of an unerring instinct, resulting from its peculiar organization, does mechanically construct its cells; but the polype is incapable of forming, or even modifying its support or cell, in the slightest degree. The frame-work or skeleton is *secreted* by the animal tissues, in the same manner as are the bones and other parts in the higher order of animals, without the individual being conscious of the process. If a piece of white coral be immersed in dilute hydrochloric acid, the calcareous portion will be removed, and the secreting membrane, in the form of a flocculent substance, be seen attached to the undissolved part; and even in some coralline marbles, although of incalculable antiquity, the animal matter may in like manner be detected. M. C. 271.

192. Genus ASTREA, (*star-like corals.*) *Description.*—Polyparium massive, irregular in shape or globular, formed by an aggregation of laminated, radiated, shallow polymorphous cells.

The species of this genus are among the most numerous of the corals of the oolite, and the older secondary formations; and with several other genera, form those coralline beds, often many feet in thickness, which pervade some of the strata, and are in fact coral reefs, that have accumulated beneath the sea, in the places they now occupy. Some specimens of the Astrea are remarkably beautiful, being composed of five or six-sided figures, from the centres of which the stellate rays all diverge.

Lign. 31. *Fig.* 1. *Astrea ananis*, Devonshire. *Fig.* 1*a*, a polished slice of marble of the same species. *Fig.* 2. *Syringopora ramulosa*, Devonshire. *Fig.* 3, a fragment of *Favosites gothlandica*, Ohio, by Dr. Owen. *Fig.* 4. *Anthophyllum Atlanticum*, United States, by Dr. Morton. *Fig.* 5. *Caryophyllia annullaris*, oolite.

There are perhaps hundreds of varieties of fossil corals,

What is the error about the construction of corals?

LIGN. 31.

Fossil corals.

some of which, when polished, form remarkably beautiful specimens. They are mostly calcareous petrifactions, though sometimes silicious. Mr. Mantell describes one from Wiltshire, found in large hemispherical masses, completely silicified, a transverse section of which displays, in some specimens, beautiful white radiated stars, on a dark-blue ground; and in others, the colors of the stars and ground are reversed, the stars being blue and the ground white.

GEOLOGICAL DISTRIBUTION OF FOSSIL ZOOPHYTES.

193. We have more than once remarked, in the foregoing pages, that the lowest orders of animal existences were found in the lowest, or oldest formations. Thus, the extinct polyparia, are none of them found in a recent strata, but all in the earliest geological periods in which there are any signs of vitality.

About three hundred and fifty species of this family are enumerated in Morris' Catalogue of British organic remains. These being all found in that country without

reference to those at present known and named in France, Germany, Italy, America and other countries, this number itself is sufficient to indicate that a much greater aggregate of names could at the present time be exhibited. And yet little comparatively is known of the whole number of genera and species, which will hereafter be discovered and named, as the necessary labors of man progress in excavating the same formations in different parts of the earth, in which they are known to exist in England.

The tertiary formations contain the sponges, and a few species of corals not contained in the secondary; while the secondary, immediately preceding the cretaceous formations, namely, the lias and oolite, contain vast numbers of zoophytes, of nearly every family known. The corals and shells are all of extinct species; of these, the oolite have yielded about two hundred species. In the Silurian rocks, entire beds, composed almost exclusively of polyparia, and of considerable extent, are found; and in the same strata in this country, the same description of coralline marbles exist. This would seem to prove that a more equal temperature prevailed on the earth at that geological period, than at the present time, when these polyparia exist only in tropical climates. It is said that the reef-forming genera are now confined to waters where the temperature is not below 70°, and that their most prolific development is where the temperature is not below 75°.

COLLECTING FOSSIL ZOOPHYTES.

194. The minute corals of the chalk are to be obtained by the same process as that directed for the infusoria. The large examples should be left attached to a piece of chalk, or the material in which it is found, when practicable, and the surrounding stone removed with a knife or graver, so as to expose as much as possible of fossil, without loosening its attachment to the block. When the investing chalk is very hard, frequently penciling the specimen with vinegar, or dilute hydro-chloric acid, will soften the stone, and render its removal easy, by means of a soft brush; when acid is employed, the specimen must afterwards be well washed in cold water. It may, perhaps, be well to caution the collector against employing sulphuric acid for this purpose; for a

white insoluble deposit, sulphate of lime, will thus be formed on the specimen, which cannot be washed off and thus it will be nearly ruined.

CHAPTER XVII.

LILY-SHAPED ANIMALS, STAR-FISH, SEA-URCHINS.

195. The term *Echinoderma*, (*spiny-skin*,) is applied to this class, consisting of three families, viz. : the Crinoidea, or *stone-lilies*, as they are called ; the Stelleridæ, or the *star-fishes*, and the Echinidæ, or *sea-urchins*.

The star-fish, and the sea-urchins, are well known, and quite popular living families, there being hardly a collector with a dozen specimens on his shelf, where more or less of these tribes are not to be seen. The lily animals, on the contrary, are mostly an extinct race, there being, it is said, only two representatives of the family in the living state. These are the Caput Medusa and the Comatula, both of the West Indies.

Genus Crinoidea.—This includes the whole family of lily-like animals, which is however divided into several species, or varieties. The fossil remains of the Crinoids consist of the *ossicula*, or little bones of the column, arms or tentacula ; of the plates of the receptacle ; and of the foot-stalk or stem by which it was permanently fixed to the rock in the sea. The foot-stalk is in some instances flat, and expanded like the gorgonia, or sea-fan ; in others it is round, consisting of hundreds of little circular bones, laid one on the other, and fastened together by a membrane, allowing motion in all directions, like the spine of a snake. In other varieties, this part is pentagonal, or five-sided, and hence this variety has the name of *Pentacrinite*, (In Dr. Buckland's *Bridgewater Geology*, this family has had much attention bestowed upon it, many of the varieties, with the forms of the ossicula and of their stems, being figured and described.)

The detached bones, and portions of the stems, are so common in some of the English lime-stone quarries that the little round bones are well known among the people

under the name of *wheel-stones*. In the north of England they are called *fairy-stones* and *St. Cuthbert's beads*.

196. *Encrinite.*—The generic names of this family terminate with *crinites* (*stone-lily*). Thus, the *pentacrinite* means five-sided stone-lily, in allusion to its five-sided stem. *Apiocrinites*, *pear-shaped*, in allusion to the pyriform head. The term formerly employed for the whole family, and before the species were distinguished by different names, is still retained, and applied to that variety which most resembles a lily, or tulip, viz.: *Encrinite*, or *Encrinus*, which is the true lily-form variety. This is represented by *Fig.* 1, *Lign.* 32, and is remarkable for the elegance of its form, and the fine state of preservation in which it is often found. The specific name is *Encrinus liliformis*. The column or stem

LIGN. 32.

Fig. 1.

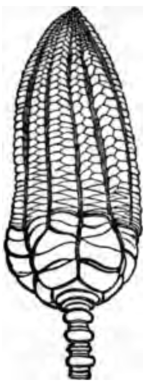
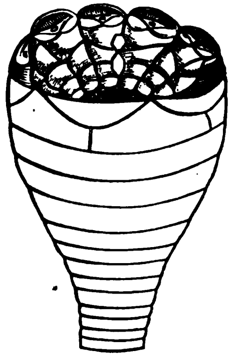


Fig. 2.



Encrinites.

is composed of numerous perforated, round, flat-joints, articulated by a radiated or grooved surface, the ossicula, of which the whole is composed, being alternately larger and smaller, thus allowing great freedom of motion. This variety is found in abundance in various places in England, as well as on the continent, and in this country.

Apiocrinites rotundus, or *pear-encrinite*, *Fig.* 2, abounds in the limestones and clays of the oolite, in various parts

of England. It is also found on the continent, and in the state of Ohio. The column or stem of this species is composed of round, even, ossicula, or articulations with radiated surfaces, and an opening or perforation through the centre. The arms of this specimen are broken off, as is nearly always the case in this variety.

With respect to the habits of these animals, they were all attached to stones at the bottom of the sea, and therefore could extend their motion in every direction to the length of the column or stem, and no further. This probably varied from a few inches to a foot or two. The arms, represented as closed in fig. 1, are composed of little bones, or ossicula, like the stem, and indeed all the other parts. These the animal had the power of spreading out like a star, for the purpose of grasping its food, and bringing it to the mouth, which was situated in the centre, or at the base of this curious apparatus. When one of the arms or tentacula were broken off, it appears that the animal had, like the lobster and crab, the power of reproducing it. Thus, many instances have occurred, where these parts were in the process of reproduction, presenting a small short arm, instead of the full-sized like the others.

The number of bones of which the lily-encrinite was composed and which formed the great bulk of the animal, amounted to many thousands. Mr. Parkinson (*Organic Remains*) had the curiosity to count them in a specimen, in a superior state of preservation, and found the number at least twenty-six thousand.

197. Says Dr. Buckland, (*Bridgewater Treatise*,) "The physiological history of the family of the Encrinites is very important; their species were numerous among the most ancient orders of created beings; in this early state, their construction exhibits at least an equal, if not a higher degree of perfection, than is retained in existing species of Pentacrinites; (Caput Medusa and Comatula); and although the place which, as Zoophytes, they occupied in the animal kingdom, was low, yet they were constructed with a perfect adaptation to their low estate, and in this primeval perfection they afford an example at variance with the doctrine of the progression of animal life, from simple rudiments, through a series of gradually improving and more perfect forms, to its fullest development in existing species."

198. STAR-FISHES.—The star-fish, popularly so called, are very common along the sea shores in all parts of our country. The common species have five rays, with a groove on the under side, along which are perforations, and through them are protruded or retracted small tubular tentacula. The mouth is situated in the centre of the under surface. They are rough on the upper side, with small tubercles, containing pores. Their color is brown or reddish; their motions slow, and their appearance disagreeable. There are several species, all of which have their rays elongated, so as far to excel in length the diameter of the disk. Some of the fossils of this family are formed very nearly like the recent species above described, while others consist of five angles, or projections, with a large disk, the whole hardly amounting to the stellate form.

199. Genus GONIASTER, (*Cushion-star.*)—The star-fishes of this genus are of a pentagonal form, and bordered with marginal plates. There are some recent examples of this family which are beset with spines, though no traces of them can be detected in the fossils. The frame of the cushion star-fish is composed of ossicula, many of which are often found in the chalk formations.

200. FOSSIL ECHINIDA, or *Sea-urchins.*—The relics of this family are among the most familiar objects known as petrifactions. Their enveloping cases or crusts are of considerable durability, and hence have served as molds, into which flint, calcareous spar, or other mineral substances, when in a dissolved state, have percolated, and upon consolidation have formed sharp enduring casts, exhibiting the forms of the plates of which the shell was composed, the disposition of the pores, &c., thus forming a very perfect cast of the interior of the whole.

The common Echinus of our sea coasts, called *sea-egg*, or *sea-urchin*, presents the usual characters of the fossil species.

The globular shell of some species is composed of numerous calcareous plates, exquisitely put together, and arranged in elegant patterns; appearing like the lines of the meridian on an artificial globe. The plates are disposed in vertical series, united by finely serrated sutures, forming five-sided figures. The plates are ornamented with tubercles, between which are lines of pores, or aper-

tures, by which the animal protruded its feet or tentacula. The tubercles vary in size, from mere grains to large mammillated protuberences. To these the spines are or were attached by exceedingly fine muscles, thus forming the ball and socket, or universal joint. In some varieties there passed a ligament from the ball to the centre of the socket, as in the human thigh bone. It is very difficult to obtain even recent specimens with all the spines attached. Whether the animal has the power of throwing off, or disjointing these arms, like the crab and lobster, we know not; but it is rare, even in the most numerous collections, to see a perfect specimen, that is, one with all its spines in their places.

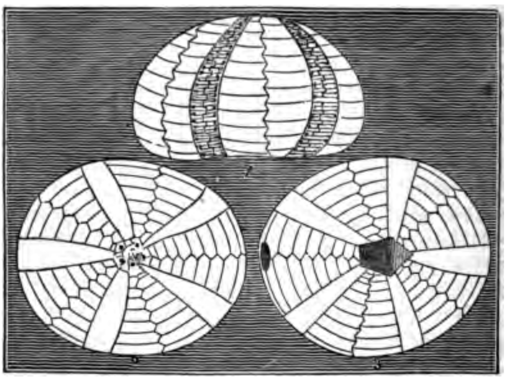
The spines or arms are the organs of loco-motion in all this family, and with which they not only contrive to move with comparative celerity, but also to bury themselves in the sand; and it is probably owing to the latter circumstance, that such numbers of them are found in so perfect a state. The forms of these organs vary much in the different species, being in some, thin, long and pointed, like needles; in others thick, with blunt points, and in others elongated ellipses, their outlines resembling paddles. The orders and species of this great family are so numerous and interesting, that treatises of considerable length have been occupied in their illustrations and descriptions; and at the present time M. Agassiz, of Switzerland, is preparing a work on the "Recent and Fossil Echinidæ."

201. Genus Cidaris, *Turban echinus.*—This includes the globular, depressed, and spherical species, having the mouth in the centre below, with an outlet opposite, on the summit. The shell is composed of twenty vertical series of plates, the *ambulacra*, or porous grooves, forming continuous bands from the summit to the mouth, which is armed with five angular teeth. This group comprises many of the most elegant fossil species, some of which, from their shape and beautifully ornamented surfaces, are called "fairy night-caps" and "turbans." The genus varies, from an inch to two or three inches in diameter, and we regret that our limits will not allow figures of a few of the varieties. They occur in the oolite and chalk formations.

202. Genus Galerites, (*cap-shaped.*)—This genus is only found in the fossil state. The species are known by their

regularly circular, or polygonal shell, which is flat below and conical above, and formed of dissimilar plates, covered with minute tubercles. The ambulacra, or grooves of pores, are narrow, and vary in number from four to six in the different species; they pass from the summit to the mouth. The species of this genus are very numerous, and in some chalk formations are found in incredible numbers. Sometimes the specimens obtained from chalk are filled with flint, and these, when the shell which remains outside is dissolved in hydrochloric acid, afford exquisite casts. By this means, the form of the plates, and casts of the minutest pores, are stereotyped on the remaining silex, giving imperishable and exact representations of the inside of the shell.

LIGN. 33.



Galerites.

The *Galerites castanea* is represented by *Lign.* 33, *Fig.* 1, showing the form of the shell, being flat below and conical towards the apex. *Fig.* 2, shows the conical part of the shell, viewed from above, showing the rows of ambulacra, passing from the summit to the base or mouth. *Fig.* 3, the base, showing the pentagonal mouth, and the vent in the margin.

The Echinites, unlike the fixed Encrinites, have a progressive motion through the water, which they effect by the rapid motion of their arms or spines. With these,

which in some species amount to a great number, they rise or sink at pleasure; and as they have a motion in all directions, while they employ some as oars, others can be used in catching food, and conveying it to their mouths. In some respects they are among the lowest orders of animal existences, but in others they are wonderfully made, having apparently the most perfect adaptation to their modes of life, and the means by which they subsist.

ON COLLECTING THE FOSSIL ECHINODERMA.

203. In searching for fossil Crinoideans, the receptacle or head should be the principal object; and if only detached plates can be found, their natural position should be carefully noted, and the specimens glued to a card or board in that order; and some of the ossicula of the arms, or stem, if found, be placed with them.

The *star-fishes* are so simple in form and structure, that it is hardly necessary to offer any suggestions for their development; of course, the more perfect they can be obtained, the better, and to do this, they must not be removed from the stone.

In collecting the Echinides, much caution is required, especially in dissecting specimens surrounded by spines. If imbedded in hard limestone, or in laminated clay, it is hardly possible to succeed; but it often happens that the Cidarites of the oolite are attached by the base to the solid limestone, while the body, with the spines, is imbedded in clay, or in the sandy friable, aggregate, not difficult of removal. The chalk Echini will be found to possess spines more frequently than could be supposed, if care be taken to explore the surrounding stone before it is removed. Sometimes the Cidarites, with spines may be obtained, when there was no manifest evidence of these appendages, by carefully scraping away the surrounding mass until the extremity of a spine appears, and the tracing it to the body of the shell. The chalk around the situation of the mouth, should always be carefully removed, in hope of preserving the teeth.

As the shells of Echinides, when hollow, are often lined with crystals, it is best to break indifferent specimens of the common species, in hope of discovering such examples M. C. p. 360.

CHAPTER XVIII.

DISTRIBUTION AND GROWTH OF TESTACEA.

204. THE *Testacea* are molluscous, or soft-bodied animals, having a hard or shelly covering, as the snails, oysters, clams, &c.

Geographical distribution of the Testacea.—"The testacea," says Mr. Lyell, "of which so great a variety of species occurs in the sea, are a class of animals of peculiar importance to the geologist; because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings. Climate has a decided influence on the geographical distribution of species in this class; but as there is much greater uniformity of temperature in the waters of the ocean, than in the atmosphere which invests the land, the diffusion of many marine mollusca is extensive.

205. *Great range of some species.*—Some few species of this family are found at immense distances from each other, and no doubt exist in all the intervening spaces. Thus the *Cypræa moneta* or money shell, which is used in some parts of India instead of coin, is found in the Mediterranean, in South Africa, the Isle of France, the East Indies, in China, the South Seas, and even as far west as the Sandwich Islands. The *Turbo petracus* also inhabits the seas of England, Guadaloupe, and the Cape of Good Hope. This would seem to show that there are some species of testacea, as in plants and some of the higher orders of animals, which have the power of enduring a wide range of temperature. Thus, the willows are found from the banks of the Jordan to Siberia; and the rat and fox inhabit nearly every part of the earth.

206. *Confined range of others.*—Mr. Lowe enumerates seventy-one species of land mollusca, collected by him in the islands of Maderia and Porto Santo, sixty of which belonged to the genus Helix (*snail,*) of which forty-four are new species. It is remarkable, that very few of the above genera are common about the Canaries, and still more so, that of sixty species, thirty-one are natives of Porto Santo; whereas in Madeira, which contains ten times the superficies, were found but twenty-nine. Ot

these only four were common to the two islands, though separated only twelve miles apart.

The confined range of these mollusca may be easily explained, if we admit that species have only one birth-place; and the only problem to be solved would relate to the exceptions—to account for the dissemination of some species of land mollusca throughout the European continent. May not the eggs, when washed into the sea by the undermining of cliffs, or blown by a storm from the land, float uninjured to a distant shore?

207. *Their mode of diffusion.*—Notwithstanding the proverbially slow motion of snails and mollusca in general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are, many of them, by no means destitute of provisions for disseminating themselves, rapidly, over a wide area. Some lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a time after their birth; and this buoyant substance floats far and wide as readily as sea-weed. In rivers and lakes, on the other hand, aquatic univalves usually attach their eggs to leaves and sticks, which have fallen into the water, and which are liable to be swept away during floods. Particular species may thus migrate during a single season from the head waters of the Mississippi, or any other great river, to the countries bordering the sea, at the distance of many thousand miles. *Lyell*, *Princp.* iii. p. 145.

FORMATION AND GROWTH OF SHELLS.

208. Shells may be defined to be hard bodies, which are formed by secretion, by the soft, inarticulate animals which inhabit them. It is said by Mr. Gray, of the British Museum, who has written a memoir on this subject, that the animal, shortly after it is formed in the egg, begins to construct its shell; and, when hatched, deposits on the edge of the mouth of the minute shell which covered its body in the egg, a small portion of mucous secretion. This mucus soon grows hard, when the animal lines it with a fresh layer, composed of mucous matter, mixed with calcareous particles; and when this deposit becomes hard, it is again lined with the same kind of composition as before. This alternate deposition of mucus, and of mucus mixed with calcareous particles, proceeds as the tenant enlarges

and requires more ample cover and protection, until its habitation is complete, and suited to the wants and station of the occupant. The shell is, in truth, molded on the body of the animal, as it increases in size, forming a cover, a dwelling, a coat of mail, a shed, a boat, a ship, or a palace of pearl, as is best adapted to the exigences of the case, or the station of the builder in the scale of creation. The inequalities or irregularities of the body itself are also reproduced by corresponding protuberances on the outside of the shell; so that the elevations, depressions, fissures, tubercles, or spines, which distinguish individual species, may be considered only as the effects of corresponding projections in the form of the animal, or perhaps of its protruding tentacula.

209. Among the instructive and interesting facts shown by a suite of molluscous shells in the British Museum, on this subject, are the following: The mode of growth; the changes which take place in the shell during the increase and expansion of its inhabitant; the manner in which these animals repair any accident to their shells, or remove by absorption any portion which has become unnecessary or inconvenient. Other specimens illustrate the manner of forming a straight, or nearly straight shell, into one of the spiral variety; while others exhibit the deformities or monstrosities which sometimes afflict individuals of this class of beings.

CHAPTER XIX.

CONCHOLOGY.

210. The several parts of a shell are distinguished by different names, which, as in other sciences, have a technical meaning. Without this language, one shell could not be so described as to distinguish it readily from another. This language applies to fossil, as well as recent shells; and, therefore, before we proceed to describe and illustrate the testacea of a former world, it will be necessary for the student to understand, at least, some of the terms employed in describing the shells of the present time.

211. *Composition of Shells.*—Shells, in their recent state, are composed of carbonate of lime, mixed with a little animal or gelatinous matter. Some shells, if placed in a weak acid, will exhibit the tissue of this matter, the acid dissolving the lime, but leaving the gelatin in nearly its original state. In fossil shèlls the animal matter is seldom present, the shell itself being petrified, and its interior filled with carbonate of lime or with silex.

212. *Conchology defined.*—Conchology is the science which treats of the structure, arrangement, and properties of shells. Shells are inhabited by *testaceous* animals, and to which they are only partially attached. *Crustaceous* animals are confined entirely within their coverings, each limb or member being invested by its own peculiar shield, as in the *lobster* and *crab*. Many of the testacea are fixed by an attachment to other substances, as the oyster and muscle; while others have the power of crawling àlong the bottom, or of moving through the water, as the unio (fresh-water clam) and the scallop. The animals which inhabit shells are called *mollusca* or *molluscous* animals; but the classification depends, not on the habits or form of the animal, but on the form and other properties of the shell.

The Linnæan system of conchology, which is the most simple of any that has been proposed, divides shells into Multivalves, Bivalves, and Univalves.

By *valve* is here meant any single piece of shell, which forms the habitation, or part of the habitation, of a molluscous animal. Any shell, formed of more than two pieces, is a *multivalve.* *Bivalves* consist of two distinct pieces, and *univalves* of a single piece.

I. MULTIVALVES.

213. This is much the smallest class, but contains some beautiful shells. The genus Lepas, which contains the *common barnacle*, fig. 1, belongs here. The Chiton, or coat of mail, is another member of this class. The generic description of Lepas is, "Shell multivalve; affixed at the base; valves unequal, erect." These shells are chiefly parasitic, being attached to extraneous substances: often to ships, pieces of wood, whales, &c. Thé generic characters of this class are derived from the number and situation of the valves.

II. BIVALVES.

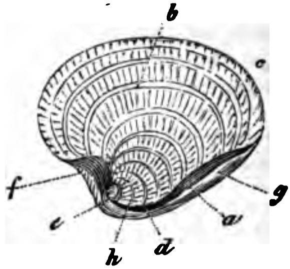
214. This class includes all such shells as are composed of two pieces only, whatever their forms or dimensions may be; and in these respects the species differ exceedingly. The two valves of the Chama gigas sometimes weigh five hundred pounds, and from this, there are all grades of size down to that of a grain of sand.

LIGN. 34.

Fig. 1.

Barnacle.

Fig. 2.



Cardium.

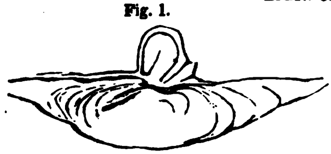
215. Bivalve shells, when their valves are similar in size and form, are said to be *equivalved;* if not similar, *inequivalved;* when the anterior part agrees in form with the posterior, they are said to be *equilateral;* if not, *inequilateral.* The valves are connected at their base by a *ligament*, with or without a hinge, the ligament being placed *externally* or *internally*. The *belly*, *a*, *Fig.* 2, *Lign.* 34, is the most tumid part; the *disk*, *b*, is that part between the belly and the *margin*, *c*, which is considered to refer to the external side, or, as it may be termed, when the shell is placed on its base, the *upper side;* then the *umbones*, (eminences) *d*, are beneath the hinge, and terminate in the *points* or *beaks*, *e*, which are *incurved*, *reflected*, or *ear-formed*. The beaks are frequently, in particular shells, accompanied by two external impressions; one of these, the *corslet*, *f*, is on the anterior surface, and is separated from the disk, generally by a ridge, an angle, or a sunken line, and is often distinguishable by its difference of color; it is sometimes spinous, carinated, lamellated, &c., but is more generally smooth, when it is said to be *naked*. The other impression, called

the *lunule*, *g*, is placed at the bottom of the posterior surface; it is variously shaped—*oval*, *oblong*, *lanceolate*, &c. The two pieces forming the shell are called the *right* and *left* valves: the shell being placed on the hinge, with the anterior side forward, that is considered as the *right* valve which answers to the left hand, the other being the *left* valve. The *length* of a bivalve is from the umbones to the margin opposite; and the *width* or *breadth*, from the end of the anterior to that of the posterior margin: hence many shells are broader than they are long: those whose length exceeds their width, are called *longitudinal*, and those whose width exceeds their length, are called *transverse* shells. Shells are distinguished by the appellations *free*, when they are capable of moving, and *fixed*, when they adhere to other bodies.

Bivalves are divided into three orders, depending on the mechanism of their hinges.

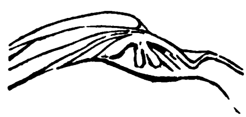
LIGN. 35.

Fig. 1.



Mya hinge.

Fig. 2.



Cardium hinge.

216. *First*. Those which are furnished with internal teeth at the hinge, but which are *not* inserted into the opposite valves, as in *Lign*. 35, *Fig*. 1. The genus Mya (to which belongs the common long clam) and Solen (razor shell) are examples.

To the Mya genus belongs the Pearl Gaper, (*Mya margaritifera*,) a beautiful shell with a pearly lustre, and which occasionally produces pearls of great value. It is found in the large rivers of the northern latitudes, and is not the shell which is the object of the regular pearl-fishers.

To this genus, also, belongs some shells in considerable request among collectors: but, on the whole, the genus is not remarkable for the beauty of many of its species.

217. *Second*. Shells which have their teeth inserted into their opposite valves, *Lign*. 35, *Fig*. 2. To this order belongs the Cardium (heart shell) and the Venus; one species of which is well known in our markets, under the name of

round clam, and which are taken in great abundance on the shores of Long Island, and sold as an article of food.

Third. Shells having a hinge, without teeth, as in the well-known shells of the oyster and scallop.

The generic distinctions of the bivalves, depending entirely on their teeth, and their genera in the Linnæan system amounting to only thirteen in number, they are easily distinguished from each other. The species depending on the forms and markings are not so readily distinguished.

III. UNIVALVES.

218. This is much the largest class, and contains a great proportion of the shells which collectors seek after with so much avidity, and many of which sell at exorbitant prices.

Univalves differ greatly from each other in form, size, and coloring. Like the bivalves, their different parts are distinguished by peculiar names, which are applied in scientific descriptions, and by means of which conchologists are enabled to understand each other.

Only the most necessary and common of these terms can here be explained.

The univalves are distinguished chiefly by the form, size, and direction of their apertures, but sometimes by the conformation of the shell.

The univalves are exceedingly numerous, of a great variety of forms, and some of them remarkably beautiful, both in shape and color. For the names of the several parts of a univalve, see *Lign.* 36, *Fig.* 1.

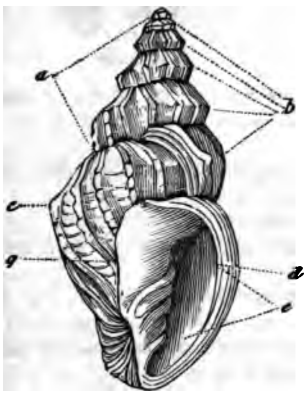
219. The spire, *a*, in the univalve, *Fig.* 1, is formed by the union of the *turns* or whorls, *b*, which are counted by reckoning the lower turn, containing the opening below, as the first, and counting on the same line to the top of the spire. The turns in most shells go from the right to the left; when they pass from left to right, which rarely happens, the shell is said to be *reversed*. The line passing round the shell like a screw, and at which the whorls are united to each other, is termed the *suture*. The whorls are *plain*, *grooved*, *crenulated*, crowned with points, &c.

The *back* of the shell, *c*, is the external, tumid part, on the opposite side, and above the aperture. The *body* consists of the whole of the tumid part, *c*, which forms the first whorl. The *opening* or aperture, *e*, is *circular*, *oval*,

angular, &c., and it is often the form of this part which determines the genus of the shell. This opening terminates in a groove or notch, which is either *straight* or turned to the *right* or *left*, or *backwards*. When the opening is longer than wide, it is said to be *longitudinal;* and when wider than long, *transverse*. The *edge*, or margin of the opening, is divided into *right* and *left lips*. The *right*, or outer lip, *d*, reaches from the body, or first turn of the shell, to the base. The *left* lip, *g*, is on the other side of the opening, and is of small extent in those shells, the openings of which are entire. This opening is filled with a body composed of shell, or cartilage, which is attached to the animal, and with which he can close the opening at pleasure, by drawing it in. This is termed the *operculum*.

LIGN 36.

Fig. 1.



Univalve.

Fig. 2.


Spiral shell.

The little white bodies, popularly called *eye-stones*, are operculums.

Univalves are distinguished into two kinds.

220. *First*. Those which are furnished with a *spire*, as *Fig*. 2, *Lign*. 36, and those having no spire.

Those furnished with spires, are again divided into such as have—1st, their apertures *effuse*, that is, having the lips separated by a sinus, or gutter, so that, if filled with water, it would flow out at the back part, as the *conus*, *cypræa*,

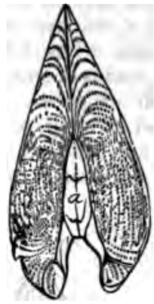
***bulla* and *voluta*. 2d. Such as have their apertures *canaliculate*, or like a canal, as *buccinum*, *strombus* and *murex*. 3d. Such as have their apertures *coarctate*, or contracted, opposed to effuse, as helix, turbo, and nerita.**

LIGN. 37.

Fig. 1.

Patella.

Fig. 2.



Pholas.

221. *Second.* Those either having no spires, or irregular, or imperfect ones. The patella, or limpet, *Lign.* 37, *Fig.* 1, is an example.

In this epitome of conchology, we shall describe a part, but not the whole of the thirty-six Linnæan genera, at the same time indicating which are recent, or now living; which are fossil, or extinct; and which are both recent and fossil.

222. Multivalves. Genus *Pholas*, *Lign.* 37, *Fig.* 2.—Shell bivalve, inequilateral, and gaping; having small accessory valves, *a*, situated on the hinge and posterior slope; hinge recurved and furnished with a tooth.

The name *Pholades*, imports *seek a hiding*, in reference to the habits of the animals, which live in limestone rocks, or wood, entering when small, and gradually increasing their cells, according to their growth. The largest specimens are found in chalk, which being a soft rock, perhaps admits of a larger growth, in consequence of the ease with which the animal enlarges its cell There is a mystery concerning the means by which these animals penetrate the substance of their future prison, which, from the size of the aperture, must be done when they are very young. The animal undoubtedly has the

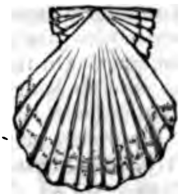
power of dissolving the stone and wood by means unknown to man. The idea of friction with the shell, is untenable, since this is covered with raised net-work, with the points sharply defined. This shell has not been found in the fossil state.

LIGN. 38.

Fig. 1.

Mytilus.

Fig. 2.



Scallop.

223. Bivalves. Genus *Mytilus*, *Lign.* 38, *Fig.* 1.—Shell longitudinal, equivalved; the beaks nearly straight, terminal and pointed; hinge without teeth. Shape either folded or lobed, crested or attenuated towards the apex. This is the *muscle* of common language. To this genus belongs the pearl-bearing shell, (mytilus *margaritiferus*,) of the Indian fisheries. The whole genus are inseparably attached to other substances.

The species in which pearls are found, are most abundant, and in the greatest perfection, on the coast of the Persian gulf and of the island of Ceylon. The term pearl-oyster is commonly applied to this shell, but incorrectly, as is obvious, since the genus is Mytilus, and not Ostrea.

In the great pearl fisheries which supply the Eastern markets, the number of fish annually brought up by divers, is almost incredible. Many of the shells contain no pearls, but some contain two or three. Those of two grains, sell from about one dollar and fifty cents to two dollars each; those of five grains, from eight to ten dollars each; those of eight or nine grains are of arbitrary value, because they are very rare. The finest specimens sometimes bring enormous prices, being considered invaluable, and fit only to adorn the persons of Eastern potentates.

Of the Mytilus, there are about forty recent, and two fossil species.

224. Genus *Ostrea*.—Shell bivalve, generally with un-

even valves, and slightly eared hinge; without teeth, but furnished with an ovate hollow, and usually with lateral transverse grooves.

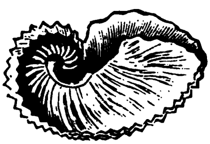
This genus includes the scallop, or pecten, *Lign.* 38, *Fig.* 2, which, however, unlike the oyster in the habit of the animal, and the general form of the shell, agrees with it in the mechanism of the hinge, the part on which the generic distinctions depend.

The loco-motive powers of the scallop are exerted in a singular manner. On the ground a rapid progress is made by opening and shutting the shell suddenly, and with so much muscular force, as to throw it five or six inches each time. In the water, an equal dexterity is evinced by the animal in raising himself to the surface; probably by the same means, and of directing his course at pleasure. When disturbed, he shuts his valves, and sinks to the bottom like a stone.

Of the Ostrea, there are fifty living, and thirty-six fossil species.

LIGN. 39.

Fig. 1.



Argonauta.

Fig. 2.

Patella.

225. Univalves. Genus *Argonauta.*—Shell an involuted univalve; the spire turned into the opening, very thin, with a tubular double dorsal keel. *Lign.* 39, *Fig.* 1.

The art of navigation is supposed to have owed its origin to one of this genus. (See *Nautilus*, page 126.) He was observed by the ancients (and subsequent experience has confirmed the observation) to raise himself to the surface of the sea, by ejecting a quantity of water, and thus diminishing the specific gravity of his vessel. When floating in a calm, he throws out two or more tentacula, or feelers, to serve as oars. If a favoring breeze springs up, he spreads a fine membraneous sail, on two extended limbs, and steering with his other arms, shows his

naval skill by numberless evolutions. In case of danger, he draws in a little water, hauls in, and coils up his tackie, and sinks to the bottom. The Argonauta is not found in the fossil state.

226. Genus *Patella.*—A shield-formed, sub-conical univalve, without a spire; sometimes with a perforation through the summit, *Lign.* 39, *Fig.* 2. *Lign.* 37, *Fig.* 1, a perforated Patella.

The name *Patella*, is from the resemblance of some species to the knee-pan. There is considerable variety in the forms of the species, but all are fixed firmly to the rocks or stones by the animal, which is covered by the shell.

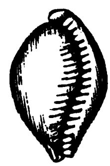
It is both fossil and recent.

LIGN. 40.

Fig. 1.

Dentalium.

Fig. 2.



Cypræa.

227. Genus *Dentalium.*—Shell univalve, sub-conical, a little curved, tubular, not chambered, open at both ends. *Lign.* 40. *Fig.* 1.

The form, as the name expresses, is like that of a tooth, or tusk, especially like the tusk of an elephant.

These shells are found partly buried in the sand, and the animal, which some naturalists have supposed to be free and unattached to its shell, may be observed to sink deeply into it, in order to avoid danger.

The species are few, and entirely recent.

228. Genus *Cypræa.*—Shell univalve, involute, obtuse, smooth; aperture effuse at both ends, linear, toothed on both sides, longitudinal. *Lign.* 40, *Fig.* 2.

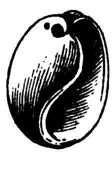
This genus is remarkable for the high polish, and often beautiful colors, with which it is adorned in its native state. Many of the species are quite common, and therefore not so highly prized by collectors as the more rare. They are often set for snuff-boxes.

The inhabitant of this shell, it is said, has the power of quitting it, and of forming a new one, better fitted to his necessities or convenience. "The Cypræa live deeply buried in the sand, from whence, it is said, at the full moon, and during its increase, they leave their habitations, for the benefit of conchologists, and crawl forth in a state of nakedness, to expatiate on the rocks above, and to begin a new dwelling." This accounts for the great numbers and high state of preservation in which these shells are found. Naturalists, however, doubt the ability of these animals to leave their shells.

The name of this genus appears to be derived from that of the Cyprian goddess, on account of the great beauty of the species.

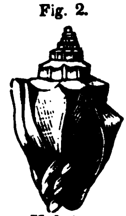
LIGN. 41.

Fig. 1.



Bulla.

Fig. 2.



Voluta.

229. Genus *Bulla.*—Shell univalve, convolute, unarmed; aperture sub-coarctate, or a little contracted, oblong, longitudinal, entire at the base. *Lign.* 41, *Fig.* 1.

The shell of this genus is inclosed in a mantle, or fold of the animal, instead of forming an exterior shield, as in most cases. Some of them are river shells, but they mostly live in the sea, buried a few inches in the mud.

The name *Bulla*, a *bubble*, is descriptive of the swelled or puffed form of the shells of most species.

230. Genus *Voluta.*—Shell univalve, convolute, columella, or pillar-plaited, or screwed, the lower plaits being the largest; it has neither lip nor umbilicus. *Lign.* 41, *Fig.* 2.

These shells are easily discriminated by the plaited columella, and by which they are particularly distinguished from the genus Conus. The plaits are longitudinally inclined, and not nearly horizontal, as in the genus Murex. The name of this genus is expressive of the form of the shell *voluta*, "rolled up cylindrically." This genus con-

tains many shells, of considerable beauty, and, on the whole, is among the most elegant known.

The recent species are numerous, besides which, many fossil species are known.

LIGN. 42.

Fig. 1.

Buccinum.

Fig. 2.

Strombus.

231. Genus *Buccinum.*—Shell univalve, spiral, gibbous, or protuberant, aperture ovate, ending in a canal turned to the right, with a short beak; interior lip flattened. *Lign.* 42, *Fig.* 1.

The direction of the canal towards the right, that is, *from* the exterior lip, is very characteristic of this genus. The name Buccinum, signifies a *trumpet*, or *horn*, but is often misapplied, since many of the species are less like a horn than those belonging to other genera.

This genus is divided into several families. The shells of some having little resemblance to each other in form; but a reference to the peculiarity of the beak will generally distinguish this genus. Fossil and recent.

232. Genus *Strombus.*—Shell univalve, spiral, expanded; aperture having the lip unusually dilated, and ending in a canal, inclined towards the left, or *from* the pillar. *Lign.* 42, *Fig.* 2.

One species of this genus is well known under the name of *Conch-shell*, the interior of which is of a beautiful pink color, and was formerly in fashion in ornamental jewelry.

Some members of this genus might easily be mistaken for Murices, or Buccina; but the Strombi have a depression, or sinus, on the dilated wing, which is separated from the groove at the base of the shell, next the pillar. Attention to this will lead to the distinction. It is both recent and fossil.

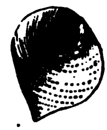
233. Genus *Murex.*—Shell univalve, spiral, often formed with longitudinal membraneous sutures; and beset with spines; aperture terminating in a canal, either straight or turned up backwards, and not inclining to the right or left. *Lign.* 43, *Fig.* 1.

LIGN. 43.

Fig. 1.

Murex.

Fig. 2.



Turbo.

The very peculiar form of the aperture or canal, is a very distinctive feature in this genus. This is oblong-oval, or perfectly oval, and does not gradually contract into a canal, like the Strombi and Buccina, but suddenly opens into it at the same, or nearly the same width, which it retains through the whole length of the beak.

The famous Tyrian purple was extracted from an animal inhabiting one species of this genus. A single vein near the head contains the coloring liquor; but the art of dyeing, in latter times, has disclosed more beautiful and much less costly colors than this produces.

The name Murex, means *rough*, or rock-like, a designation which fails to apply in many of these species. It is both recent and fossil.

234. Genus *Turbo.*—Shell univalve, spiral; aperture contracted, round and entire. *Lign.* 43, *Fig.* 2.

One of the best distinctions of this genus, is the round aperture. The shells often closely resemble those of the Trochus genus; but, in these, the aperture is angular, often the only mark of distinction between the two genera.

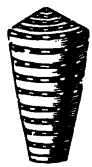
The Turbo might at first be mistaken for the spire of another shell, but its unbroken base and round aperture will generally distinguish the genus. The name Turbo, means any thing which *whirls around*, as a top, in reference to the spiral form of the genus. It is both recent and fossil.

235. Genus *Conus.*—Shell univalve and turbinate. Aperture effuse, longitudinal, linear, toothless, and entire

at the base. Columella smooth, base attenuated, sometimes marked with oblique grooves. Aperture sometimes dilated; whorls, mostly flat, often channeled, rarely crowned. *Lign.* 44, *Fig.* 1.

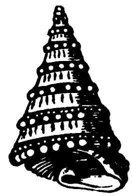
LIGN. 44

Fig. 1.



Conus.

Fig. 2.



Trochus.

236. The great beauty of this genus, both in form and coloring, renders it highly interesting and valuable to the lovers of the science. The rare species are sought after with avidity by shell collectors, and the most beautiful kinds often sell for considerable sums. The Conus *gloria maris*, and the Conus *cedonulli*, sometimes bring from twenty to twenty-five guineas for single shells.

The name Conus, *a cone*, refers to the shape of the genus.

237. Genus *Trochus.*—A spiral, sub-conical univalve; aperture four-sided, and somewhat angular, having the upper part of the margin converging towards the pillar, which is oblique. *Lign.* 44, *Fig.* 2.

In some species, the aperture tends to an oval form; but these are distinguished from the Turbines, by a tooth-like projection. It must, however, be confessed, that there is much difficulty in distinguishing some specimens of these two genera from each other. In general the Trochi have the form of a pointed cone, capable of standing nearly erect on their bases. The word Trochus, has a similar meaning to Turbo; the common name is *top-shell*, or *button-shell*, the shape being similar to that of a common spinning-top or an ancient conical button.

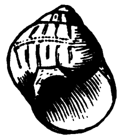
238. Genus *Helix.*—Shell univalve, spiral, translucent, brittle; aperture coarctate or contracted, lunate or circular, having the segment of another circle taken from the whole area, *Lign.* 45, *Fig.* 1. The common land snail is

a good example of this genus.—The whorls are contiguous, and the body of the shell *always* forms a lunate projection into the aperture, and this character will distinguish the Helices from the Trochi and Turbines. Another mark of the genus is tenuity, or thinness and translucency.

239 Genus *Nerita*.—Shell univalve, spiral; gibbous, flat underneath, aperture semi-orbicular, or semi-lunar, having uniformly the pillar lip, or columella straight. *Lign.* 45, *Fig.* 2.

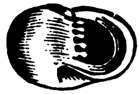
LIGN. 45.

Fig. 1.



Helix.

Fig. 2.



Nerita.

The Nerita is a genus well characterized, and therefore easily distinguished, the straight pillar lip being a uniform mark, which at once separates them from the Helices, which their forms most resemble. Nothing can exceed the beauty and delicacy with which some of these shells are marked, or the rich tints of color with which others are stained. It is both recent and fossil.

CHAPTER XX.

FOSSIL CONCHOLOGY.

240. (The terms *Testacea* and *Mollusca* are often used, so as to appear only as two words signifying the same thing; and then again the student is perplexed to find them apparently meaning different orders, or classes. The explanation is, that the two words mean different parts of the same object, the one having reference to the shell, and the other to the animal it contains. Thus, mollusca is from *mollis*, soft, meaning the animal; and testacea from *testa*, shell, meaning the hard covering. It will

be seen therefore that an oyster, is a molluscous animal, with a testaceous covering, though by many writers the terms are used indifferently to mean the same thing.)

With the exception of the Infusoria, the class of organic remains, to which our attention is now to be directed, is the most widely diffused, the most various in character and appearance, and the most numerous, which geological inquiry has brought to light.

From the permanent nature of these remains, and the immense numbers in which they are found, in all fossiliferous strata, the testacea are of great importance to the geologist. We have seen indeed (125) that the Tertiary formation has been divided into periods in proportion to the quantities of shells its various strata contain.

241. *Explanations.*—Having already given an arrangement of Fossil Remains, (178,) it is only necessary here to explain a few terms, which are more particularly applicable to the animals which once inhabited the objects of our investigation.

242. ACEPHALA, *without head.*—Because they have neither jaws, tongue, or distinct mouth. They are all aquatic, as the *oyster*, and are divided according to the modifications of their coverings.

243. BRACHIOPODA, *arm-footed.*—So called because they have fleshy *brachia*, or arms, which are attached in the usual place of feet or legs. They are inclosed in bivalve shells, and have not the power of loco-motion, being fixed to the bottom of the sea, as the *Terebratula.*

244. ENCEPHALOUS, *with a head.*—These possess a head, eyes, mouth, jaws and teeth, with tentacula, or feelers. They are free animals, and can crawl or swim; some being terrestrial, and others marine. Their shells are univales, as the *snail* and *limpet.*

245. PTEROPODA, *wing-footed.*—So called, because their organs of loco-motion are two wing-like muscular expansions, proceeding from the sides of the neck. With these they swim, and rise or sink. The *Clio* is an example.

246. GASTEROPODA, *stomach-footed.*—These crawl by means of a muscular projection, or foot, which comes from the under part of the body. The *snail*, *slug* and *limpet*, are of this sort. Most of them are of marine origin.

247. CEPHALOPODA, *head-footed.*—They have powerful muscular arms, or tentacula, around the head, by which

their motions are effected. as the Nautilus and Cuttle-fish. The latter is the only mollusk in which the hard parts are internal.

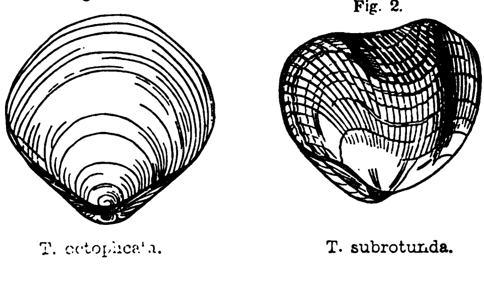
Number of the Testacea.—The number of living species of these animals. known and named, are estimated by naturalists at something more than six thousand, and almost every day is adding new species; for hardly a vessel arrives from distant seas without bringing some new shell to enrich the cabinet of the conchologist. In this country the whale ships are the most successful importers of foreign specimens. and many of the sailors are good judges of the value of a rare shell.

FOSSIL BIVALVE SHELLS.

248. TEREBRATULA.—From *terebro*, to bore, in allusion to the perforated beak (215) through which passes a byssus, or stem, by which the animal is fixed at the bottom of the sea. It is a bivalve shell of the brachiopodous order, (243.) of which a few species only exist. Of fossil species, about five hundred are known, nearly all of which are found in British strata. The most interesting circumstance relating to these mollusca, is the respiratory apparatus, which consists of two long ciliated tubes, spirally coiled, united at the base, and supported by slender calcareous processes, which are often preserved in the fossils.

LIGN. 46.

Fig. 1. Fig. 2.



T. octoplicata. T. subrotunda.

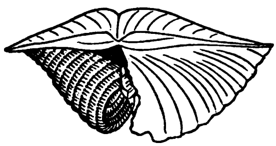
Lign. 46, represents two species. *Fig.* 1, T. *octoplicata* and *Fig.* 2, T. *subrotunda.* In both, the perforation of the beak is apparent.

249. Spirifera, *containing spiral processes.*—Among the great variety of fossil shells found, the *spirifera* have peculiar interest, on account of their calcareous processes, which in the living state supported the ciliated *branchia*, or hair-like gills, by which respiration was effected.

In many specimens this part is preserved. *Lign.* 47, *Fig.* 1, shows one of the spires, by the removal of a part of the upper valve. It is an internal apparatus, as seen, but the animal had the power of unwinding and protruding it beyond the spiral shell. The two then served, not only for breathing, but also as arms for seizing its prey. It is found in the Silurian and Devonian formations in great abundance. Three other fossil genera are known of this family and a great number of species.

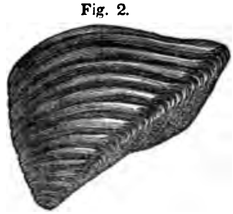
LIGN. 47.

Fig. 1.



Spirifera.

Fig. 2.



Trigonia.

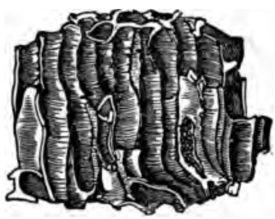
250. Ostrea.—The oyster is well known in most parts of the world as a luxurious article of food. It has no organs of loco-motion, and either fixes itself to some hard body, or lies still in the mud. There are several recent, and fifty or more, fossil species of this genus. The lower sands and clays of the London basin are underlaid with a bed of these shells, so that when the strata around that city is perforated to a sufficient depth in search of water, this bed is always pierced. This was the case lately in boring an Artesian well, the shells being found at the depth of two hundred and eighty feet. These shells closely resemble the edible species of the present day. The oyster family is distinguished by having one shell deeper than the other, and by having only one muscular impression.

251. Trigonia, *three-angled.*—The form of the shell ex-

plains its name. These shells are thick and heavy. The right valve has two large oblong teeth, which diverge from the umbo, and are strongly furrowed, and fit into two corresponding grooved cavities in the opposite, or left valve. A single living species is known to inhabit the sea of New Holland. The fossil species are very abundant in the Portsmouth oolite. *Lign.* 47, *Fig.* 2, represents one species, the *Trigonia costata*, or ribbed Trigonia.

252. TEREDO, *Ship-worm.*—It is an encephalous mollusk, one species of which, the *Teredo navalis*, commits very entensive injuries on ships, bridges, and other works of timber, exposed to their attacks. It is the most vermiform, or worm-like, of all the mollusca, and forms a tortuous cylindrical perforation in the wood, sometimes piercing through the planks of a ship, so as to endanger her safety, and perhaps complete her ruin; hence the necessity of sheathing with copper. The Teredo has a mouth, furnished with testaceous valves or teeth, by which it bores its way into the wood, secreting at the same time calcareous matter with which it lines its passage. The fossil species differ from the recent, only in the form of the valves, or teeth. They are found in petrified wood in abundance. *Lign.* 48, shows a piece of wood literally full of these destroyers. Specimens in which the wood is petrified, and the cavities of the tubes filled with calcareous spar of various colors, furnish beautiful specimens when cut and polished.

LIGN. 48.



Teredo navalis.

Dr. Mantell says, that "when the canal in Regent's park was being formed, large blocks of perforated calcareous wood were discovered, having the ligneous structure

well preserved, and the tubes of the Teredines occupied by yellow, gray, and brown spar, forming specimens of great beauty and interest."

FOSSIL UNIVALVE SHELLS.

253. The animals of the univalves are more highly organized than those of the bivalves. They are *encephalous*, (284,) and have nearly all of them the power of locomotion; while the acephalous bivalves, with few exceptions, as in the unio, or fresh-water clam, do not move from their places. They belong to the *gasteropoda*, or stomach-footed family, and inhabit severally the sea, rivers, and the land. The *periwinkle*, the *river-snail* and the *common-snail*, are well-known representatives of each of these tribes.

LIGN. 49.

Fossil Gasteropoda.

Their shells are spiral, and with a few exceptions turn from left to right, the aperture, when the shell is placed on the base, being dextral to the observer, as in *Lign.* 49, *Figs.* 1, 2, 3. In a few species, the spire turns in the opposite direction, and the mouth is on the left, as in *Fig.* 4. The shells here represented, *Lign.* 49, are Fig. 1, Palu-

dina fluviorum. 2, *Limnea longiscata*. 3, *Cerithium lapidum;* and 4, *Fusus contrarius*. The Paludina and Limnea, are common fresh-water shells, inhabiting rivers and lakes. The Cerithium and Fusus are marine. Extinct species of all these genera are found abundantly in various Tertiary formations.

254. *Geographical Distribution of Bivalves and Univalves.*—"If the more rare and splendid organic remains may be regarded as the '*Medals of Creation*,' says Dr. Mantell, the fossil testaceous mollusca, from their durability, numbers, and variety, may be considered as the *current coin* of geology. Occurring in the most ancient fossiliferous strata in small numbers and of peculiar types; becoming more abundant, and varied in the secondary formations; and increasing prodigiously, both numerically and specifically, in the tertiary, these relics are of inestimable value in the identification of a stratum in distant regions, and in the determination of the relative age of a series of deposits." M. C. 437.

255. *Fossil Cephalopoda.*—These *head-footed* animals have formed some of the most ancient and interesting among fossil remains. Most of the species are extinct, but a few are known at the present day, among which are the *Sepia*, or cuttle-fish, and the *Nautilus*. The living are, however, but a feeble representation of the countless myraids which swarmed in the ancient seas. These mollusca are composed of a body, which is either inclosed in a shell, as in the Nautilus, or contains in the interior, a solid calcareous or cartilagenous support, as in the cuttle-fish. The latter has a distinct head, with mouth, eyes, and organs of hearing. The head is surrounded by several arms, or tentacula, with which they adhere to rocks, it is said by suction, and with which they seize their prey. But the most curious and singular part of their fabrication is the apparatus by which they are enabled to move themselves through the water. This is a tube, situated below the head, by which the animal propels itself backwards, by the forcible ejection of the water that has served the purpose of respiration. Thus, the act of respiration serves this singular aquatic, instead of organs of locomotion. Its forward motion is effected by means of its tentacula.

The cuttle-fish is supported by a kind of skeleton, con-

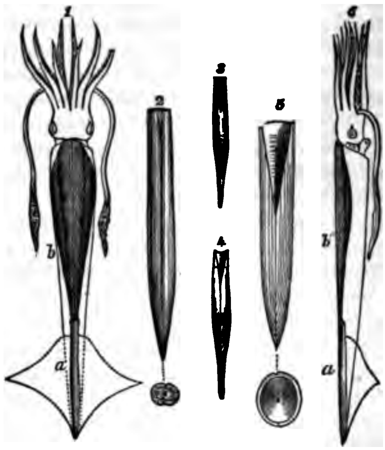
sisting of a single bone of singular structure, which, when dried and reduced to powder, is the substance called *pounce*, and is used by writers to keep the ink from spreading. This extraordinary animal has the power of secreting a dark-colored fluid or ink, which it ejects when pursued, and by thus rendering the water turbid, escapes from its enemies. This fluid is contained in a bag, which forms, when prepared, the *sepia* color used by painters. It is also said to enter into the composition of India-ink.

256. BELEMNITE, *a dart*, from the supposed resemblance of this fossil, to the head of a javelin, or dart. Among the immense variety of organic remains found in the earth, none have excited more curiosity, or given rise to more conjectures than the Belemnites. They occur in the shape of long fuciform stones, of a cylindrical shape, pointed at one extremity, and having at the larger end a conical cavity, which is either occupied by a chambered shell, or is filled by the petrifying substance. Some of them are translucent, but more commonly they are opake. Their structure is radiated, with a minute central cavity, extending their whole length. The different species vary in size, from the thickness of a quill, to several inches in circumference, and twelve inches in length.

These remarkable fossils, known to the people by the name of "Thunder-stones," are found to have been the interior support of ancient species of Cuttle-fish; the soft parts having decayed, this portion only was preserved by petrifaction. The conical cavity at the large end expanded into a thin horny receptacle, which contained the ink bag; and it is a singular fact, that the inspissated ink has been found in many cases in the bag, and as a matter of curiosity has been prepared, and recently used as a pigment.

The form of the supposed animal, being nearly that of the Sepia of the present time, is represented in *Lign.* 50. *Fig.* 1, a front view of the animal; *a*, the Belemnite, attached to the ink bag, *b*; *Figs.* 2, 3, 4 and 5 are Belemnites of different species; the figure below 2, shows the form of the aperture at the upper end; *Fig.* 5, is a longitudinal section, showing the cavity, and below its size and form; *Fig.* 6, a side view of *Fig.* 1.

LIGN. 50.



Belemnites.

NAUTILUS.

The well-known shell of the pearly Nautilus needs no description. It is what naturalists technically call a *chambered* shell; being internally divided into compartments, growing smaller as the spire diminishes. These partitions are pierced by a tube, called a *siphunculus*, which extends to the remotest cell. On sawing the shell longitudinally through the middle, the tube, partitions, and cells are displayed, affording to the sight a beautiful and interesting piece of mechanism, evidently constructed with some design, not easily comprehended. The animals which constructed these complicated shells, were unknown to naturalists until recently; for although the shells themselves probably have, from the earliest times, been common, yet the builders, it appears, have, except in a very few instances, escaped, notwithstanding the great anxiety to capture them. The writer, several years since, requested a scientific lieutenant in the American navy, who expected to spend a year or two on the ocean, and in hot climates, to procure a specimen of the Nautilus, and pre-

serve it in spirits for his inspection; but although the voyage was performed, the Nautilus, notwithstanding thousands were seen, was not procured, every attempt being without success. We also remember the statement of the celebrated French traveler Valliant, that when neaı the Cape of Good Hope, many of these little animals were seen sailing before the wind; yet the sailors of his ship, though every exertion was made, never could capture one. They would always sink before a net could be put under them.

Dr. Buckland states that the recent publication of Prof. Owen, of London, on the Pearly Nautilus, (1832,) affords the first scientific description ever given of the animal, by which this long well-known shell was constructed. The reason seems to be, that the nautilus never approaches near the shore; the instant it stops breathing, it sinks to the bottom; and having only a slight attachment to its shell, and living only in hot climates, the shell and animal soon separate—the one to drift ashore, and the other to decompose at the bottom of the ocean.

Prof. Owen's memoir has shown, that the animals which constructed the fossil Nautili, as well as those now existing, were nearly allied to the common Cuttle-fish; the principal difference appearing to be, that while the organs of the latter secrete an internal testaceous support, the instinct of the nautilus constructs a beautiful habitation, in which it can rise, sink, swim, or sail at pleasure.

Means of rising and sinking.—The means by which the nautilus so readily rises to the surface, and, on alarm, sinks like a stone—and this without fins—has been a problem among naturalists; and several theories have been offered to account for the fact. But since the anatomy of the animal has been better understood, the secret has been explained. It appears now that the chambers are filled with air, instead of water, as was supposed; and that the animal has the power of secreting a considerable quantity of fluid, which is retained within the shell by an expanded membrane; and that the sinking is in consequence of changing the place of this fluid, by forcing it in the air-cells, and at the same instant withdrawing the tentacula into the shell, thus making a compact mass of the whole. By this exchange, it will be observed that the bulk of the

air is diminished by condensation, exactly on the principle that the little images descend to the bottom of the glass jar, when the India-rubber is pressed which is stretched across its mouth. In this philosophical toy, the images are tubes of glass, the upper parts of which contain air, and the lower water, so as just to balance them in the fluid. Now, when this air is condensed, by pressing the water higher in the tube, the image begins instantly to sink; but begins to rise again when it expands by removing the pressure. Thus, the nautilus, having descended by forcing the fluid into the air-cells, through the siphuncle or tube, (which communicates from one cell to the other, through the series,) rises again by allowing the fluid to return to its sack, and the air to expand: a wonderful provision, it is true, but completely solves the mystery so long an enigma with respect to the motions of this celebrated animal. The sailing of the nautilus, which it can only do before the wind, is performed by expanding its membraneous tentacula, which at other times are employed in seizing and conveying its food to the mouth.—Bd. p. 232—252.

257. Fossil Nautili.—The British strata alone contain about sixty species of the Nautilus. These are found in the Tertiary, Carboniferous, and Cretaceous formations. The shells all possess the general characters of the recent species, above described, though often differing greatly in external form.

258. Ammonites.—So called, from their supposed resemblance to the horns engraven on the heads of Jupiter Ammon. The shell is compressed, with the whorls of the spire contiguous and visible; septa or partition lobed, with a sinuated margin; border of the lip thickened, often notched and auriculated; siphon or aperture near the back of the shell.

These are among the most common and abundant fossils of British secondary strata. They appear to have been known under the name of *snake-stones*, from very early times; and there are still local traditions among the people of England, ascribing their origin to swarms of snakes, turned into stones by the prayers of some patron saint. The Lias in Yorkshire contains vast numbers of these remains, of several species. The species known in that country amount to about two hundred, being common

in all the secondary formations, but are rarely found in the tertiary. Mr. Mantell states, (M. C. p. 493,) that they vary in size, from half an inch to *four feet in diameter.*

This animal, like that of the nautilus, occupied the outer chamber of the shell, which, however, extended to a comparatively greater depth than in the shell of the nautilus. No representative of this family has been found in the recent state. They were of marine origin, and vary greatly in form, some being of an elegant figure, and beautifully ornamented; their outlines being a gentle curve, the folds not being contiguous, as in most of the species. One of these, *Lign.* 51, *Fig.* 1, called CRIOCERAS, or *curved horn*, is among the most graceful of this family. The more common form, with the spire involuted, and the turns contiguous, is represented by *Fig.* 2. Nearly all the Ammonites are casts, and therefore represent the inner forms and markings of the shells, the shells themselves having disappeared.

LIGN. 51.

Fig. 1.

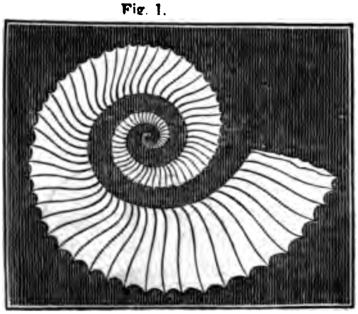
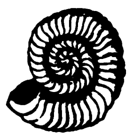


Fig. 2.



Fossil Ammonites.

259. TRILOBITE, (tres, *three*, *and* lobus, *a lobe.*)—An order of Crustaceans, embracing those remarkable fossils in which the body is divided into three lobes by two fissures, running through the length. These, originally called *Dudley insects*, (from their being found in great numbers in the town of Dudley, in Staffordshire, England,) have been objects of great interest to the naturalist for more than one hundred and fifty years. Linnæus placed

them among the insects; but later observations have shown that they are among the extinct crustaceous mollusks. The most common examples consist of a convex oblong body, divided transversely into three principal parts, and longitudinally into three lobes. They had a distinct head, with eyes, but no antennæ; no signs of feet or legs have been discovered, and it is therefore supposed that these were soft or membraneous, and decayed before petrifaction was effected.

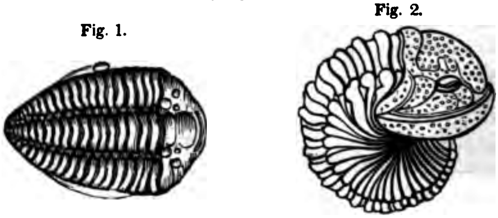
These fossils are very abundant in the Silurian and other formations in England. They are also found in profusion in similar formations in various parts of this country, and particularly at Trenton falls, New-York.

This numerous family has been divided into many genera, though few of their names have any reference to their natural characters, but only to the obscurity which still seems to invest the whole order. Thus, Asaphus, *obscure*, Calymene, *concealed*, Agnostus, *unknown*, and several others, of similar import, are examples.

260. *Calymene Blumenbachii*, *Lign.* 52, *Fig.* 1.—This is one of the common species. It is deeply trilobed, and has fourteen transverse segments. It varies from one to fourteen inches in length. *Fig.* 2, the same coiled up, like a millepede, and seen in profile.

LIGN. 52.

Fig. 1. Fig. 2.



Fossil Trilobites.

261. ISOTELUS, *Equal extremities.*—In this species, the body is of an oval shape, and the posterior angles of the head are rounded; the thorax is composed of eight segments. Some American species, belonging to this genus, are of enormous size. The *Isotelus gigas*, discovered by Dr. Dekay, of New-York, measured eighteen inches in length. But Dr. Locke describes and figures one, in his

report on the Geology of Ohio, of still more gigantic size, being twenty-one inches in length: this he very properly calls the *Isotelus maximus*. These are much the largest specimens ever discovered. In Great Britain, it is rare to find any of the tribe more than five or six inches in length.

FOSSIL INSECTS AND SPIDERS.

262. The Insects have a head, compound eyes, and jointed antennæ. The wings of those which fly, are attached to the middle and third segments of the thorax. The legs are articulated, or jointed, and contain the muscles on the inside of a crustaceous covering. The genera are founded on the structure, and configuration of the antennæ and wings. The latter consist of thin membraneous expansions, supported by hollow tubes, called *nervures;* and, in some orders, consist of one pair, as in the butterfly, and in others two, as in the dragon-fly. In burrowing insects, as the beetle and horn-bug, the front pair of wings is formed of a hard case, called *elytra*, which covers the membraneous, or flying wings, when the insect is at rest

The wings being the foundations of the orders, the divisions are the following: 1. *Coleoptera*, (sheathed wings,) as the beetle, and other flying insects, generally called *bugs*. 2. *Neuroptera*, (nerved wings,) as the *Libellula*, or dragon-fly: these have two pair of membraneous wings. 3. *Hymenoptera*, (membraneous wings,) as in the bee: the wings are veined, but have no reticulated nerves. 4. *Lepidoptera*, (scaly-winged,) as in the butterfly, the dust of whose wings are little scales, regularly disposed. 5. *Diptera*, (two-winged,) as in the house-fly: behind the wings are appendages for balancing the insect.

The remains of insects found as fossils are not common, though the elytra being the most enduring part, might be supposed at least as indestructible as many remains found in a perfect state. And yet any part of an insect is rarely found; and, on this account, these to the geologist are the most precious and interesting relics of a former world.

Dr. Buckland, however, in the *Bridgewater Treatise*, has described and figured a few specimens of scorpions, spiders, and other insects. But these are in so mutilated a state as to make it difficult to decide their place of arrangement.

The detached wings of various species of the Neuroptera have also occasionally been discovered; and Dr. Mantell has figured a single specimen of the dragon-fly, in a good state of preservation, with the exception of the loss of one of the four wings.

CHAPTER XXI.

FOSSIL ICHTHYOLOGY.

263. ICHTHYOLOGY, signifies a discourse on fishes. The whole structure of a fish is as well adapted for swimming as is that of a bird for flying. Being suspended in a fluid of nearly the same specific gravity with itself, it needs no expanded organs for its support. Many species have the air-bladder so organized and developed, as, by its contractions and dilatations, to vary the specific gravity of the fish, and thus to enable it to sink to the bottom, or rise to the surface, without the help of the fins.

The animals we have heretofore examined are called by naturalists *invertebrated*, that is, without back-bones. Those we are now to describe are *vertebrated*, so called from *vertebræ*, which means *to turn*, as the spinal column in all animals has motion in every direction. Of vertebrated animals, the fishes are among the lowest orders. Instead of lungs, they respire by means of BRANCHIÆ, or gills, and their loco-motion is performed by fins, instead of feet.

The living species of fish known to naturalists are estimated at about eight thousand; and those in the fossil state, according to M. Agassiz, most of which have been determined by himself, at present amount to about fifteen hundred; while several hundreds still remain undetermined.

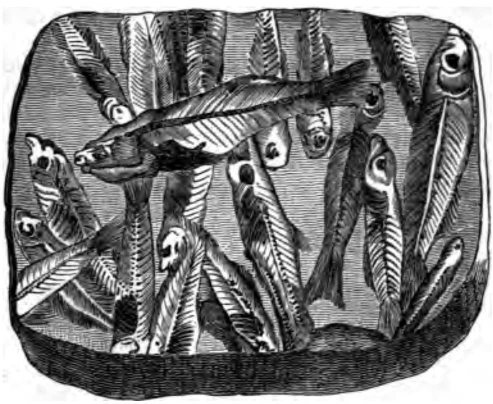
"The fossil remains of the fishes," says Dr. Mantell, "rank in the first class of the '*Medals of Creation*,' for they demonstrate the existence of numerous tribes of highly organized beings in the most ancient fossiliferous strata, and the continuance of the same type of organization,

What does Ichthyology mean? What is said of the structure of fishes? Why are fishes called vertebrated animals? How do fish respire? What number of living species are there? What number of fossil?

variously modified, through the entire series of subsequent deposits to the present time. Each geological formation contains peculiar groups of fossil fishes, distinguished by distinct modifications of structure. Thus, according to the data at present obtained, all osseous (bony) fishes anterior to the chalk formation, belong to genera which have no representatives among existing species; and they are characterized by rhomboidal scales, covered with enamel." M. C. p. 591.

Sedimentary strata, composed of mud and fine sand, of whatever age, have been most favorable to the preservation of the entire forms of fishes. In such strata of the tertiary system, and in the chalk of England, are sometimes found fishes quite perfect in form; and not only individuals, but groups, with the scales, fins, head, teeth, and even the capsules of the eyes, in their natural position. A small slab from Aix, in Provence, *Lign.* 53, is an example.

LIGN. 53.



Fossil fishes.

The fishes are of diminutive size, and of a family unknown at the present day; the name, *Lebias cephalotes*, o. Agassiz. In the orders of this grand division of the vertebrata, M. Agassiz, of Switzerland, the author of a great work on the fossil fishes, has been guided by the peculiar structure of the scales, and it is obvious that this

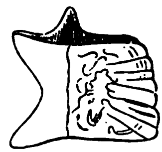
method is quite simple and easy for the learner, since it requires no examination of the bones, or other parts of the structure. In most instances, the scales and bones are the only parts remaining, of this class of fossils. The following is his division:

LIGN. 54.

Fig. 1.

Placoid.

Fig. 2.



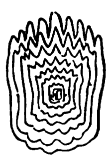
Ganoid.

264. Order I. PLACOID, (*a broad plate.*)—The skin is covered irregularly with enameled plates, sometimes of a large size, but frequently in small points, as in the skin of the *shark*, called *shagreen*, and in those of the *dog-fish* and *ray*. *Lign.* 54, *Fig.* 1.

Order II. GANOID, (*splendid*,) from the brilliant surface of the enamel.—The scales are of an angular form, and composed of plates of horn or bone, covered with enamel. Their structure is identical with that of the teeth. The *sturgeon* is an example, *Fig.* 2. This order contains more than sixty genera, of which fifty are extinct.

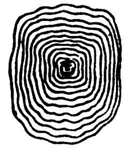
LIGN. 55.

Fig. 1.



Ctenoid.

Fig. 2.



Cycloid.

Order III. CTENOID, (*comb-like.*)—The scales are formed of plates which are pectinated, or toothed on their posterior margins. As the plates are superimposed on each

How has Agassiz divided the fossil fishes? What are the names of the orders, and their meaning? Give examples of each order.

other, so that the lowermost always extend, beyond the uppermost, their numerous and sharp points render these scales very hard to the touch. The *perch* belongs to this order. *Lign.* 55, *Fig.* 1.

Order IV. CYCLOID, (*a circle.*)—The scales are composed of simple round or oval plates of bone, or horn, without enamel, and with smooth borders; but their surfaces are often ornamented with figures or markings. To this order belong the *mullet*, *salmon* and *carp*. *Fig.* 2.

265. *Advantages of the above system.*—The system upon which M. Agassiz has established his classification of recent fishes, is, in a peculiar degree, applicable to fossil fishes, being founded, as above shown, on the characters of the external coverings or scales. This character is so sure and constant, that the preservation of a single scale will often announce the genus, and even the species of the animal from which it was derived, just as a single leaf, as we have already seen, determines to which of the great Botanical classes the tree belonged. (95.)

A further advantage, says Dr. Buckland, arises from the fact, that the enameled scales of most fishes, which existed during the earlier geological epochs, rendered them much less destructible than their internal skeletons; and cases frequently occur, where the entire scales and figures of the fish are perfectly preserved, while the bones, within these scales, have altogether disappeared; the enamel of the scales being less destructible than the more calcareous material of the bone. Bd. p. 205.

It appears that the character of fossil fishes does not change *insensibly*, from one formation to another, as in the case of the zoophytes and testacea; nor do the same genera, or even the same families, pervade successive series of great formations; but their changes take place *abruptly*, at certain definite points in the vertical succession of the strata, like the sudden changes that occur in fossil reptiles and mammalia.

266. FINS OF FISHES.—These are named according to the situations they occupy on the fish. The *pectoral*, are those on each side of the chest; the *dorsal*, those of the back; the *ventral*, those of the under parts; and the *caudal*, that of the tail. In the fossil state, the fins are often

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What are the advantages of this system? What analogy is there between the scale of a fish and the leaf of a tree, in leading to results?

beautifully preserved; even the soft rays in many of the tertiary marls, and in the chalk, are found entire and attached to the body in their natural situations.

TEETH OF FISHES.

267. Of all the durable parts of animal remains, the teeth of fishes present by far the most numerous and striking modifications of form, structure, composition, mode of arrangement and attachment; and yet their dental organs, separately considered, do not in many instances, either in their structure or mode of implantation, afford characters by which the natural affinities of the original can be ascertained; and without the aid of other parts of the skeleton, it is often impossible to determine whether an unknown form of tooth belonged to an animal of the class of fishes or reptiles. M. C. 509.

Mode of attachment.—The mode of arrangement, as well as of attachment, in the teeth of fossil fishes, is much diversified. In some, all the dental organs are of one kind and form, and are disposed in four rows, one on each side of the jaws; but in a large proportion of fishes, there are several species of teeth, which are implanted, not only in the jaws, properly so called, but on the bones which form the cavity of the mouth, on the arches of the palate, and on the tongue.

The teeth are composed of a dense bony material, termed *dentine*, which, in many species, forms on the external surface of the tooth, a cover of a firmer texture than the interior, and which has a glossy outside like enamel.

268. *Form of the teeth of sharks.*—Of all the teeth found in the fossil state, those of the *shark* are the most common and numerous. They not only occur in great numbers, but in numerous forms, indicating a great variety of species. In this family, the osseous bases of the teeth are attached, by a ligamentous substance, to the cartilaginous jaws; the teeth of these fishes are, therefore, generally found detached in the fossil state, owing to the decomposition of this substance.

Although the modifications of form are not easily enumerated, they are referable to four principal types; namely, the conical, the flattened, the prismatic, and the cylindri-

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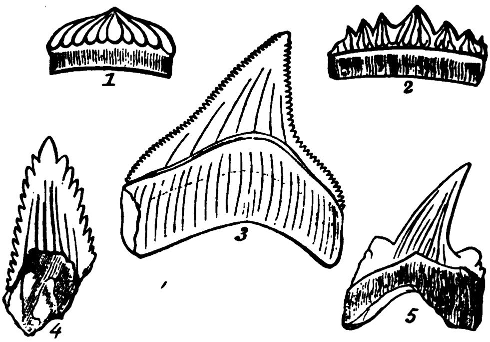
What is said of the number and durability of the teeth of fishes? What is said of sharks' teeth in particular?

cal. The sharks belong to the *Placoid* order, their scales consisting of enameled plates and tubercles, the latter forming the well-known *shagreen*. There are a few representatives of the fossil species, one of which, found on the coast of New Holland, is called the *Port-Jackson* shark, which has sixty teeth in each jaw. These present a most formidable array of instruments, for holding, cutting, and grinding the prey of this monster of the deep.

LIGN. 56.



Fossil sharks' teeth.

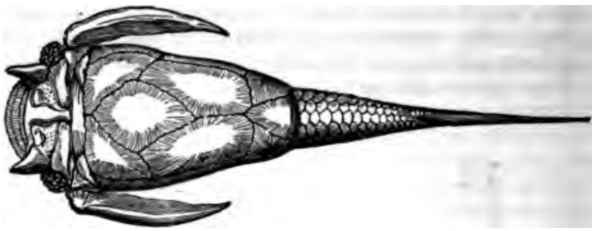
We have represented a few forms of fossil sharks' teeth, in *Lign.* 56. *Figs.* 1 and 2, are the crushing teeth of the genus *Hybodus*, of the natural size. *Fig.* 3, one of the cutting teeth of the genus *Carcharias*. It is finely serrated, and presents a formidable instrument enough, when it is considered with what force the owner had the power of pressing, perhaps, a hundred of such lancets into the flesh of its hapless victim.

The *White Shark*, now chiefly found in hot climates, has teeth of a similar construction, and is supposed to be an example of this family. Some of these are said to be forty feet in length, having jaws and teeth in proportion. But even these were greatly exceeded in size by some fossil species, whose teeth, found at the island of Malta, are said to be six inches in length. *Fig.* 4 and *Fig.* 5, cutting-teeth of the same family, natural size.

To what order do the sharks belong? What are the characters of this order?

These, and a great variety of others, of similar character, are found in the English tertiary and chalk formations.

LIGN. 57.



Winged-fish.

269. PTERICHTHYS, (*winged-fish.*)—This is a restored specimen, formed of many detached pieces, but none being admitted which did not clearly belong to this singular fish. The upper surface, or back, is represented by *Lign.* 57. The head and anterior part of the body, are covered with large scutcheons, or bony plates, of angular forms, and fitted nicely to each other. The eyes are small, and on each side of the head is a process of considerable length, moving in all directions, and which appears to have been a weapon of defense, like the horns of the common bullhead, (*Cottus gobio.*) In some specimens, these are extended at right angles with the body. The tail is of an angular form, nearly as long as the body, tapering to a point, and without a fin. This is supposed to have been the chief organ of locomotion.

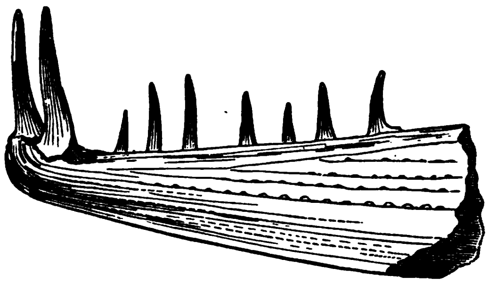
The British species of this curious creature, of which six or eight are known, are less than a foot in length; but some of the same family, found in Russia, are several feet long.

270. SAUROCEPHALUS, (*lizard-head.*)—The teeth of this genus of extinct fishes, present a most formidable appearance, resembling those of the lizard family, and hence the name. They have been found in the chalk of Sussex, England; and similar examples occur in Missouri and New-Jersey, in this country. The specimen, *Lign.* 58, is a por-

What is said of the Winged-fish?

tion of the lower jaw, with one row of elongated, slightly curved pointed teeth, the two anterior, or front ones, being much longer and larger than the others. The figure represents the left branch of the jaw, and a fragment of the right, with the front tooth remaining. These fishes belonged to the Cycloid order, having scales of a circular form. The teeth are generally of a dark color, have a glossy surface, and are very brittle, differing remarkably from the sharks' teeth, which are commonly white and firm.

LIGN. 58.



Lizard's head teeth.

271. Geological Distribution of Fossil Fishes.—It is stated by M. Agassiz, the great investigator of this department of geology, that the Ichthyolites (*fossil fishes*) of the tertiary deposits approach most nearly in their characters to living genera, but that none of these ancient families, so far as is known, have any existing representatives. In some of the newer formations, where the teeth of sharks are found in such abundance, a few have been attributed to genera now living in hot climates, but none to recent species. It is believed that the only instance in which naturalists have claimed identity of species in fossil and existing fishes, is in reference to a little fish of the genus *Mallotus*, and species *villosus*, now living on the coast of Iceland; fossil specimens of which are found along the coast of that island, of apparently recent date, and probably now in the progress of formation.

Did any of the fossil fishes belong to living species? What is said of the teeth of sharks in this connection? What instance of identity in a recent and fossil species?

In the chalk formations, numerous teeth of sharks, and nearly perfect specimens of the Cycloid, or fishes with round scales, are found. In the tertiary clays and sands, detached teeth of sharks are also obtained in a perfect state of preservation, and should be arranged on trays in the usual manner of small shells.

272. Dr. Mantell cautions collectors who visit Monte Bolca, and other celebrated localities of fossil remains, against the frauds practiced by the quarry-men, as well as the professed dealers in fossils. Specimens, apparently perfect, are ingeniously constructed from fragments of various examples. Thus, the head of one fish, the body of another, decorated with the fins of a third, and perhaps the tail of a fourth, all of different species, or perhaps genera, are dove-tailed together, colored and varnished, so as to deceive the common observer, and occasionally even the experienced collector. Sponging with cold water will often detect the imposition; for the color, if artificial, will be removed, or rendered paler, while the same process will heighten the natural tints. M. C. p. 682.

CHAPTER XXII.

FOSSIL REPTILES.

273. The animals comprehended in the class of Reptiles, which occur in the fossil state, are the following, namely:

I. THE CHELONIANS, OR TORTOISES.

These have a heart with two auricles, the body supported by four feet, or paddles, and enveloped in two osseous shields, or bucklers, consisting generally of many plates of bone, or *shell*, as it is usually called.

II. THE SAURIANS, OR LIZARDS.

These have a heart with two auricles, the body being supported by four feet, with the body and tail covered with scales.

What are the characteristics of the Chelonians? What of the Saurians?

III. THE OPHIDIANS, OR SERPENTS.

These have a heart with two auricles; perform locomotion by means of movable scales, but are destitute of feet.

IV. THE BATRACHIAN, OR FROG TRIBE.

These have a heart with one auricle, the body naked, with rudimentary ribs, and four feet.

Most of the Reptiles breathe by branchiæ or gills, in their young state, and by lungs afterwards. A familiar example is the common frog, which begins life in the form of a dark, oval animal, with a tail, living under water, and called *polywog*. It afterwards loses its tail, acquires four legs, and has its gills replaced by lungs. All the Reptiles are cold-blooded animals, and most of them remain in the torpid state during a part of the year.

274. Age of Reptiles.—Cuvier the founder of Palæontology long since asserted that there was a period, when the lakes, rivers and seas of our planet swarmed with reptiles; and that cold-blooded, oviparous quadrupeds, of appalling magnitude, were once the principal inhabitants of the dry land.

Subsequent discoveries have served only to confirm this assertion, though, at the time it was made, it would have been considered mere romance, had it come from the pen of any less authority. The progress of discovery has disinterred in the Lias, Oolite, and Chalk formations in various parts of the earth, the remains of vast numbers of Reptiles of different species, some of them of enormous magnitude, and differing entirely from those now inhabiting the sea or land. At what period of time these animals so mightily prevailed, geologists do not profess to know; but the most ancient remains of this class were deposited before what is called the tertiary period; since in the strata of these formations, occur the remains of Reptiles which approach to recent types, and which are intermingled with the bones of mammiferous quadrupeds, some of which might claim relationship of those now in existence.

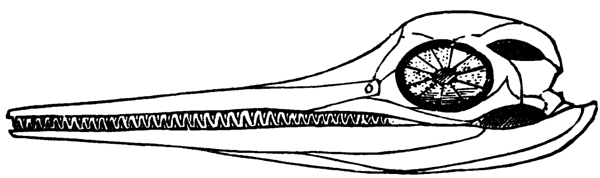
275. Teeth of Reptiles.—Prof. Owen, states, "that in

What are characteristics of the serpent and frog tribe? What is said of the age of reptiles? And why was it so called?

no reptile does the base of the tooth terminate in more than one fang, and this is never branched. Any fossil, therefore, which exhibits a tooth implanted by two fangs in a double-socket, must be mammiferous, since the socketed teeth of reptiles have but a single fang; and the only fishes' teeth which approach such a tooth in form, are those with a bifurcate base, belonging to certain sharks." The collector who observes these facts may therefore decide with certainty, and at once, to which of these great classes his specimen belongs, and which in some cases might save him a deal of perplexity, and hours of time.

In most reptiles the teeth are very numerous, some individuals having more than two hundred. In certain genera they are implanted on the jaws only; in others they occupy the vault of the mouth, as in certain fishes. In some they are anchylosed, or joined by bone to the jaw; in others they are set in distinct sockets, as in the Crocodile and Plesiosaurus; and in others still, as the Ichthyosaurus, they are arranged in a deep furrow, and retained only by the integuments.

LIGN. 59.



Head of the Ichthyosaurus.

276. ICHTHYOSAURUS, (*fish-lizard.*)—The living Ichthyosaurus must have resembled the Grampus or Porpoise, with the addition of four large flippers, or paddles, and a long tail, having also a vertical caudal-fin of moderate dimensions. The orbit of the eye is exceedingly large, sometimes fourteen inches in diameter, and the sclerotic coat, or capsule of the eye, has in front an annular series

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How will you know the teeth of reptiles from those of the mammalia? What is said of the number of teeth in reptiles? What does Ichthyosaurus mean?

of bony plates, as shown in the head of this reptile. *Lign.* 59. This peculiar structure is not possessed by fishes, but is analogous to that of some other reptiles, as the turtles and lizards, and also occurs in the eye of certain species of birds, as the owl and eagle. The teeth are very numerous, amounting to about two hundred, and are placed in a single row on each side of the jaw, being implanted in a deep continuous groove. In its dental arrangement, as well as in the form of the teeth, this animal more nearly resembled the crocodile than any living reptile.

The jaw of the ichthyosaurus is composed ofmany thin plates, so arranged as to combine strength, elasticity and lightness, in a greater degree than could have been effected by a single bone, as in other animals. This seems to have been a provision to compensate for the great length and slenderness of the lower jaw, which no doubt was moved by powerful muscles, and which, had it been composed of a single bone, would have been much more liable to be fractured in seizing and holding the prey, than if constructed of many pieces, having a motion on each other.

The vertebral column of this reptile was composed of more than one hundred joints, or pieces, resembling in structure those of fishes. To these were joined slender ribs, divided at the upper ends into two parts, and continued along the back-bone from the head to the pelvis, in this respect agreeing with the structure of the lizards.

The ichthyosaurus had four paddles, which appear to have been very powerful instruments of loco-motion. In some species each paddle was composed of about one hundred bones, bound together with strong ligaments, and covered with a thick skin. Prof. Owen thinks it probable that it might have possessed the power of some degree of motion on the land, crawling on shore like the crocodile to deposit its eggs, for it was an oviparous, or egg-laying animal.

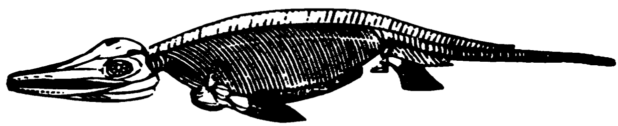
There are seven or eight known species of this genus, some of which are supposed to have been at least thirty feet in length.

An entire skeleton is represented by *Lign.* 60, but it

What is said of the jaws of the Ichthyosaurus? What is said of its paddles? How many species? What length?

must not be supposed that the whole was found at any one place: on the contrary, it is composed of the united parts of many skeletons, as they occurred in a more or less perfect state. In some, a few ribs and vertebræ might be undecayed, while the other parts were missing, or so imperfect as not to be extracted from the stone in which it was imbedded, and so of the other portions. To form a whole skeleton, therefore, was a work of time and labor; and although detached bones of this reptile are not uncommon in many secondary formations, yet only a skeleton or two, possessing nearly all the bones, has ever been constructed, many parts being composed of wood or cement.

LIGN. 60.



Skeleton of the Ichthyosaurus.

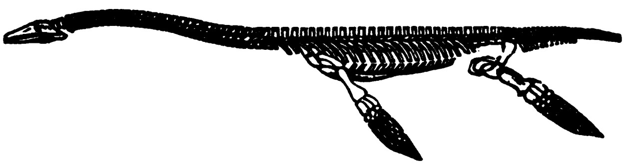
277. PLESIOSAURUS. (*lizard-like.*)—This, like the reptile just described, was a cold-blooded, oviparous animal, which presents in its osteological structure remarkable deviations from all known animals, whether recent or fossil. If we can imagine a being which unites at once the body and head of the lizard, (the former having paddles instead of feet); the teeth of the crocodile; the neck of the swan, elongated to twice its usual length; together with the agility of the crane in darting upon its prey, we shall probably have as good an idea of this marine monster, as can be obtained at the present day. The neck in most animals is formed of only five vertebræ: in the swan, it is formed of twenty-four; and in the Plesiosaurus, of forty; being four times the length of the head, and equal to the entire length of the body and tail. The teeth are placed on each side of the jaws, and are about one hundred and forty in number. They are long, slender, conical, pointed, and slightly curved inward, presenting a most for-

Was the skeleton of the Ichthyosaurus found entire, or made of the parts of several? What does Plesiosaurus mean? What description can you give of this animal?

midable and efficient means, with its long neck, of seizing and holding its prey.

That it was an aquatic animal, is proved from the form and size of its paddles; that it was marine, is shown by its remains being always associated with those of the sea; and that it breathed air, is demonstrated by its whole form. With respect to its habits, Mr. Conybeare supposes that it swam upon or near the surface of the water, arching its long neck, like the swan, and occasionally darting down its small head at the fish which happened to float within its reach. It may, perhaps, have lurked in shoal water along the coast, concealed among the sea-weed, and raising its nostrils above the water, have found a secure retreat from its more terrible enemies. *Lign.* 61, represents the skeleton of this reptile.

LIGN. 61.



Skeleton of the Plesiosaurus.

There are sixteen species of the Plesiosaurus, known to geologists, all of which have been found in the limestone formations, Lias and Oolite.

278. CROCODILES.—Naturalists enumerate twelve species of this family now living. Of these, eight species are true crocodiles, with short, broad snouts; three are called *alligators*, differing little from the crocodiles; and one, called *gavial*, which lives in the Ganges, with a slender beak, constructed to feed on fish.

Of this family, found in the fossil state, none appear to differ materially from those now existing; though it is a curious fact, that those with broad snouts, resembling the alligator, are found in the tertiary strata, but not below it; while those with elongated beaks, resembling the gavials, are only found in the secondary strata.

What is said to be the habits of the Plesiosaurus? What are the number of the species of the Crocodile?

279. CETIOSAURUS, (*whale-like lizard.*)—This genus was established by Prof. Owen, from specimens of vertebræ, and bones of the extremities of a gigantic reptile found in various tertiary deposits, in different parts of England. The originals are supposed to have been marine aquatics, and must have rivaled even modern whales in bulk, some specimens indicating a length of forty or fifty feet. They are believed to have been web-footed, and to have had broad vertical tails.

280. DINOSAURUS, (*fearfully-great lizard.*)—This term is employed by Prof. Owen, to designate the order of extinct colossal reptiles, including the *Megalosaurus*, *Hylæosaurus* and *Iguanodon*, each of which forms a well-established genus.

LIGN. 62.

Tooth of the Megalosaurus.

MEGALOSAURUS, (*great lizard.*)—This genus was founded by Dr. Buckland, from specimens of organic remains found at Stonesfield, in England. No skeleton, in which all the parts are preserved, has yet been found; but so many perfect bones and teeth have been discovered, that the peculiarity of the animal has been clearly made out, and the forms and dimensions of the limbs are as well known, as though they had all occurred in a single block.

From the size and proportions of these bones, as compared with existing lizards, it is concluded that the Megalosaurus was an enormous reptile, measuring from forty to fifty feet in length, and partaking the structure of the crocodile. From the structure of the teeth, it is proved to have been a carnivorous animal, (*Lign.* 62,) while other parts showed that it was a cold-blooded terrestrial.

What was the Cetiosaurus? What was the Megalosaurus? What the Hylæosaurus?

281. Hylæosaurus, (*wood-lizard.*)—This is another reptile allied to the Saurians, and named, by Dr. Mantell, the *Wealden lizard* from the formation where its remains were found. Only detached bones have yet been discovered, but sufficient for the learned and zealous author of the "Medals of Creation," to institute a new genus, which is supposed to have been a formidable family, of twenty or thirty feet in length.

282. Iguanodon, (*iguana-toothed.*)—The Iguana is a land lizard of the West Indies, and to which the fossil teeth of the present genus has a near resemblance, hence the name. The genus was established by Dr. Mantell, from bones chiefly found at Tilgate forest, in Sussex, England. The remains found at this locality are represented in fourteen quarto plates, many of which are occupied by the bones and teeth of the Iguanodon. As in most other cases of large fossils, only detached parts have been discovered in the same spot, and it often requires the utmost skill of the comparative osteologist to identify the bones belonging to the same species, so as not to join in the same skeleton parts belonging to different species or even genera.

"Although," says Dr. Mantell, "much remains to be known of the osteology of the Iguanodon, it is manifest, from data hitherto obtained, that the original was a terrestrial oviparous quadruped, of gigantic proportions; combining with its reptilian organization, the massy, cumbrous limbs of the existing herbivorous pachydermata, or rather approximating to the Dinotherium, Megatherium, and other extinct colossal mammalia." The probable size of the animal, according to the estimate of Prof. Owen, is as follows: length of the head, three feet; of the trunk, twelve feet; of the tail, thirteen feet: total length, twenty-eight feet.

283. Pterodactylus, (*wing-fingered.*) *Lign.* 63.—The extinct reptiles denominated *Pterodactyles*, are unquestionably the most marvelous, even of the wonderful beings which the relics of the age of reptiles have enabled the palæontologist to reconstruct, and place before us in their natural forms and appearance. With a head and length of neck, resembling that of a bird, the wings of a bat, and

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What does Iguanodon signify? Describe this animal? Describe the Pterodactylus?

the body and tail of an ordinary land animal, these creatures present an anomaly of structure as unlike their fossil contemporaries, as is the duck-billed Platypus, of Australia, to existing animals. The skull is small, with very long beaks, which extend like those of the crocodile, and are furnished with upwards of sixty sharp pointed teeth ; the orbit of the eye is very large, rendering it probable that these animals were nocturnal, and lived on insects. The fore-finger, being a division of the wing, is immensely elongated, for the support of a membraneous expansion, as in the bat, and the fingers terminated, as in that animal, in long curved claws. M. C. p. 762.

LIGN. 63.

Pterodactylus.

Dr. Buckland says : "It is probable that the Pterodactyles had the power of swimming, which is so common in reptiles, and which is now possessed by the vampire bat, of the island of Bonia. Thus, like Milton's fiend, all qualified for all elements and all services, the creature was a

fit companion for the kindred reptiles that swarmed in the seas, or crawled on the shores of a turbulent planet."

"The fiend,
O'er bog, or steep, through strait, rough, dense or rare,
With head, hands, wings, or feet, pursues his way,
And swims, or sinks, or wades, or creeps, or flies."
Paradise Lost.

"With flocks of such-like creatures flying in the air, and shoals of no less monstrous Ichthyosauri and Plesiosauri swarming in the ocean, and gigantic crocodiles and tortoises crawling on the shores of the primeval lakes and rivers, air, sea, and land, must have been strangely tenanted in those early periods of our infant world." Bd. p. 174.

Naturalists are acquainted with eight species of this wonderful animal, differing in size from a snipe to that of a cormorant.

284. CHELONIANS, (*tortoises.*)—These are distinguished from other animals by the double osseous shield, or carapace, in which their bodies are inclosed, and from which the head, neck, tail and legs are protruded, when the animal is in motion; but when disturbed, or in danger, all these parts are drawn within the shell for protection. The breast-plate, which is the true sternum, is composed of nine pieces of shell, eight of which are in pairs, the ninth being placed between the four anterior plates. In young land and fresh-water tortoises, there are vacancies between the pieces, which are filled up in the adult, and the whole united into one bony plate; but in the marine turtles, these pieces do not completely unite, the interspaces always remaining. All the Chelonians are edentulous, or toothless, their bony jaws, being raised along the edges, serve instead of teeth to seize and hold their prey, like the mandibles of a bird.

There is a close approximation of the generic characters of the fossil tortoises to those of the present day, so that it will be unnecessary to give any further description of an animal, more or less examples of which exist in every part of the world. Those found in the fossil state are of marine origin, some of which are of immense size, the shell of one described by Cuvier being eight feet in length.

What are the Chelonians? How is this order distinguished from al other animals? How do fossil tortoises differ from the recent?

The remains of both land and marine tortoises have also been discovered in England, Germany, and India. Dr. Buckland figures one with the upper shield, ribs and head, with all the legs and toes, with one exception, entire. They occur chiefly in the tertiary and cretaceous deposits.

285. Ophidians, (*serpents.*)—The fossil remains of serpents have been found in various parts of England, especially in the London clay, on the coast of Sussex, some of which are supposed to have been more than twenty feet in length. Prof. Owen infers, from the examination of these bones, that they belonged to species allied to the Boa and Python, now only inhabiting hot climates.

Batrachians, (*frogs.*)—The skeletons, vestiges of the soft parts, and imprints of the feet of several genera of the soft parts, and imprints of the feet of several genera of the Frog tribe, occur in the fossil state in many tertiary deposits, all of which, like the existing races, appear to belong to fresh-water, or terrestrial species.

CHAPTER XXIII.

ORNITHOLITES, FOSSIL BIRDS.

286. "Except in strata of comparatively modern origin, the remains of birds, in the fossil state, are exceedingly rare. In the caverns that contain the skeletons of carnivorous animals, and which were once their dens, and are now their sepulchres, the bones of several species of existing genera of birds have been discovered in England, on the Continent, and in Australia; and very recently there have been obtained from alluvial deposits in New Zealand the skeletons of birds of enormous magnitude, and under conditions which leave some doubt whether, like the *Dodo*, the species may not have been extirpated by man during the last few centuries; or even if some stray individuals of the race may not, according to the belief of the Aborigines, be still in existence in the interior of the country." M. C. p. 795.

What are Ophidians? Are any of their remains fossils? What are the Batrachians? Are any fossil? What does Ornitholites mean?

The fossil remains of birds consist of their osseous skeletons and of detached bones, and rarely of the feathers and eggs. From the quarries of gypseous limestone near Paris, Baron Cuvier obtained many bones, and some connected portions of the skeletons of several birds, related to the pelican, sea-lark, curlew, woodcock, owl, buzzard, and quail. Two or three ornitholites have been discovered at Montmatre, the celebrated fossil mine near Paris, in which almost the entire skeleton is preserved. In one example, described by Cuvier, the remains of a bird are displayed in such a manner as to show that the animal had fallen on its belly, and became partially impacted in the soft gypsum, which is now become solid stone; and that previously to its becoming completely enveloped, the principal part of its head and the left leg were removed, either by the agency of some voracious animal, or by the action of water, after decomposition had commenced. In a few instances, the petrified eggs of aquatic birds have been discovered.

287. *Ornitholites in caverns.*—In the fissures and caves of limestone districts, the remains of birds, with those of other animals, have frequently been found. Thus, in the cave of Kirkdale, in Yorkshire, intermixed with the bones of Lions, Bears, and Hyenas, Dr. Buckland discovered the remains of the Raven, Lark, Duck, Pigeon, and Snipe; all, however, of different species from those now existing.

288. Ichnolithes, (*foot-prints on stone.*)—In 1828, Dr. Duncan published an account of foot-marks and tracks of animals made in stone, at the depth of forty-five feet from the top of the rock. Similar marks were found, not on a single stratum only, but on many successive strata, showing that these impressions were made, and repeated at intervals of time. These fossil foot-marks, the first, it appears, which excited the attention of geologists, occurred in a sandstone quarry in Dumfriesshire, Scotland. Dr. Buckland, to whom Dr. Duncan communicated the facts, with drawings of the marks, concluded that they were impressions left by the feet of land tortoises. Bd. 199.

In 1831, Mr. Scrope found rippled markings, and abundant foot-tracks of small animals, in the forest marble beds near Bath, in England.

What birds have been found in the fossil state? What is the meaning ot Ichnolithes? When was the notice of geologists first called to this subject?

In 1834, impressions of animals on sandstone were found in a quarry in Saxony. The largest mark seems to have been by the foot of a marsupial quadruped, and was eight inches long. Others were attributed to tortoises, and others to batrachians (286) of gigantic sizes.

The quarries of Storeton-hill, near Liverpool, are celebrated for the abundance and variety of these fossil imprints; on some of the layers, not only the tracks of animals that have walked over the clay when soft, are distinctly observable, but the surface often presents a blistered or warty appearance, being covered either with little hemispherical eminences or depressions, which an accurate investigation has proved to have been produced by showers of rain.

The foot-prints on these strata are of several kinds; some appear to have been produced by small reptiles and crustaceans; but the principal are identical with those which have been observed in Saxony, and are referable to some large quadruped, in which the hind were of much larger size than the fore-feet. M. C. 810.

289. ORNITHICHNITES, (*fossil foot-prints of birds.*)—We have seen, above, that the tracks of animals on sandstone strata had, for a series of years, drawn the attention of geologists. These, so far as hitherto known, had been the impressions of reptiles, or of unknown quadrupeds; and it is perhaps unaccountable that the imprints of birds (a class of animals, of which many, at the present day, are constantly walking along the shores of lakes and rivers,) should not, until recently, and in this country, have been discovered and described. It appears, however, that the foot-prints of birds were first noticed in the sandstone strata on the banks of the Connecticut, by Doctor Deane, and by him described as a new and highly curious geological phenomenon.

Says Dr. Mantell: "A most unexpected and remarkable discovery has been made by an eminent physician, Dr. James Deane, of Greenfield, which seems to prove incontestably that numerous birds, and some of gigantic size, existed at the period when the Triassic, or *New Red* strata, were in the progress of formation." M. C. p. 808.

When and where were the tracks of animals in stone first noticed? What is the meaning of Ornithichnites? Who first discovered bird-tracks in stone?

Again, 810: "In certain localities of the New Red sandstone, in the valley of the Connecticut, numerous tridactyle markings had been occasionally observed on the surfaces of the slabs of stone when split asunder, in like manner as the ripple-marks appear on the successive layers of sandstone in Tilgate forest. Some remarkably distinct impressions of this kind happening to attract the attention of Dr. James Deane, that sagacious observer was struck with their resemblance to the foot-marks left on the mud-banks of the adjacent river by the aquatic birds which had recently frequented the spot. The conviction that the imprints on the stone were referable to a similar origin with those on the mud, was so strongly impressed on his mind, that he immediately collected a series of specimens, and communicated his discovery and opinions to Prof. E. Hitchcock, who followed up the inquiry with a zeal and success that have led to the most interesting results. No reasonable doubt now exists that the imprints in question have been produced by the tracks of bipeds, impressed on the stone when in a soft state."

290. "These highly interesting specimens of the ornithichnites of North America, collected and developed by Dr. Deane, have been lately added to the collection of organic remains in the British Museum. They exhibit several varieties of foot-prints, and are in a very fine state of preservation The surface of the largest slab is eight feet by six, and bears upwards of seventy distinct impressions, disposed in several tracks."

One of these tracks, of comparatively small size, is represented by *Lign.* 64; the surrounding surface of the stone being sprinkled with the impressions left by drops of rain. The imprint of the bird is of the natural size; and the following is Dr. Deane's description of the foot-marks and the strata on which they were found, in various places along the banks of the Connecticut. This, and other statements, it appears, were received by the geological savans of England with great incredulity, nor were they convinced of the truth of such phenomena, short of ocular demonstration. When it was stated that birds had lived in America, whose tracks were fifteen by ten inches, (that

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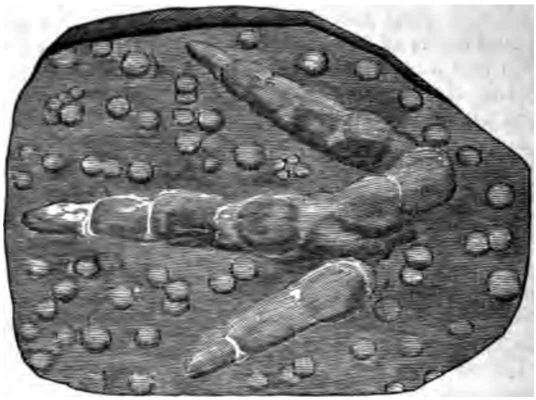
What does Dr. Mantell say is proved by the discovery of Dr. Deane? How large was the block, and the number of tracks on it, which Dr. Deane sent to the British Museum?

of the African ostrich being only ten inches long,) we are ready to excuse those who had spent their lives in developing the hidden mysteries of geology, for not at once believing that a new coin, of such enormous dimensions, should so unexpectedly be added to the "*Medals of Creation.*"

LIGN. 64.



Bird-tracks and Rain-drops.

291. *Extract from Dr. Deane's statement.*—"In general, distinct evidence of the peculiar phalangeal structure of the toes of the birds is wanting; each toe appears to be formed of a single joint, without the terminal claw. But a few specimens have been discovered, in which the true characters of the feet are clearly developed, with its rows of joints, and its claws and integuments. So far as my observations extend, the sharpest impressions are on the shales of the finest texture, with a smooth glossy surface, such as would retain the impressions of rain-drops, (*Lign.* 64.) The layers of stone do not often present this kind of surface; but recently it has been my good fortune to discover a stratum containing, in all, more than one hundred most beautiful impressions of the feet of four or five

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What were the dimensions of the largest bird-tracks? How does this compare with that of the ostrich?

varieties of birds; the whole surface having been pitted by a shower of rain. The impression of a medallion is not more sharp and clear than are most of these imprints; and I would suggest that their remarkable preservation may probably be ascribed to the circumstance that the entire surface of the stratum was incrusted with a layer of micaceous sandstone, and which adhered so firmly, that it could not be removed without the laborious and skillful application of the chisel. The appearance of this glossy layer, which is of a gray color, while the slab is of a dark red, seems to indicate that it was washed or blown over the latter while in the state of loose sand; thus filling up the foot-prints and rain-drops, and preserving them unchanged in the smallest particular; the form of the nails or claws, and joints, and the deep impressions of the distal extremity of the tarso-metatarsal, or shank-bone, being exquisitely displayed. The great slab, which is about six by eight feet in dimensions, and two inches in thickness, contains above seventy-five impressions." M. C. p. 812.

292. This slab, now in the British Museum, (presented by Dr. Deane,) is figured by Dr. Mantell, in his "*Medals of Creation*;" and the following are his remarks on the subject:

"The enormous size of some of the foot-marks are calculated to excite great surprise. I have in my possession (through the kindness of Dr. Deane) imprints that prove the size of the foot to have been fifteen inches in length and ten inches in width, exclusive of the hind claw, which is two inches long. The foot-prints of this bird, when in a consecutive series of five or six, are from four to six feet apart, which of course must have been the length of the stride of the bird: the longest stride was probably made by the animal while running; the shortest, when walking at a moderate pace. These foot-steps indicate proportions so far exceeding those of all known living bipeds, (for the foot of an African ostrich is but ten inches long,) that the geologist may be pardoned for hesitating to adopt the opinions of the American savans, in the absence of any relics of the osseous structure of the supposed birds, although sanctioned by the high authority of Dr. Buckland, who, from the first, concurred in the views of Prof. Hitchcock. But much scepticism prevailed among our geologists concerning the true nature of these impressions; and I can-

didly confess my incredulity, until a series of specimens sent me by Dr. Deane, (and which were laid before the Geological Society of London,) accompanied by a graphic description of the circumstances connected with their position in the strata, brought conviction to my mind." M. C. p. 816.

293. DINORNIS, (*fearfully-great birds.*)—"An insuperable obstacle," continues Dr. Mantell, "to the adoption of the views of the American philosophers, with some distinguished geologists, was the enormous size of the largest foot-prints; but this objection has been removed by a discovery as unexpected and marvelous as that of the Ornithichnites of Connecticut: namely, of the skeletons of several species of unknown birds, with feet equal in magnitude to the largest [of these] foot-prints, in the alluvial deposits of existing streams and rivers in the north island of New Zealand."

These bones have been described by Prof. Owen, who refers them to the Ostrich family, but to a species one-third larger than any now existing. He regards the *Dinornis* as an apterous, or wingless race, which seems to have flourished at the epoch of the *New Red* sandstone of Connecticut. Among these remains are a *tibia*, (large bone of the leg,) twenty-eight and a half inches long; a *femur*, (thigh-bone,) fourteen inches long and seven and a half inches in circumference. The native inhabitants believe that similar birds are still in existence in some part of their island. M. C. p. 818.

CHAPTER XXIV.

FOSSIL MAMMALIA.

294. THE class *Mammalia*, as its name implies, includes all milk-giving animals, whether they inhabit the land or sea. The whales, though commonly considered as fishes, are not properly such, since they are air-breathing, milk-

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What is said of the fossil birds of New Zealand? What animals does the class Mammalia include? How does it appear that the whale is not a fish?

giving, warm-blooded, vertebrated animals. Hence the whales, and several other marine tribes, with man, and all mammiferous quadrupeds, come within the same class.

The remains of this class that have been discovered in the fossil state, include a great number of species, furnishing examples of almost every living genus; also, of numerous genera, and even orders, of which no existing analogues are known. "Yet," says Dr. Mantell, "amidst the vast accumulations of the skeletons of the higher order of the vertebrata contained in the superficial drift, and in tertiary deposits, belonging to species which have successively appeared on the surface of our planet, flourished for indefinite periods of time, and then become annihilated, no vestiges of *Man*, or his works, have been detected."

Formerly it was supposed that the fossil bones of a man had been detected in a limestone quarry at Guadaloupe, and the skeleton, still partially imbedded in the calcareous deposit, is now to be seen in the British Museum. But although these remains have suffered incipient petrifaction, they are considered of modern origin, since the water in the locality where they were found is constantly depositing calcareous matter; and hence the original of these relics may have lived only a century or two ago.

295. The fossil remains of Mammalia which have hitherto been discovered, belong to one or the other of the following orders:

I. Cetaceans. *Whales*, of which there are many species.

II. Ruminants. *Cud-chewers*, as the Ox, Deer, and Elk.

III. Pachydermata. *Thick-skinned*, as the Elephant, Rhinoceros, and Mastodon.

IV. Edentata. *Toothless*, that is, without front teeth, as the Sloth, Ant-eater, and Megatherium.

V. Rodentia. *Gnawers*, as the Hare, Beaver, and Rat.

VI. Marsupialia. *Pouched*, having an abdominal bag, in which they carry their young, as the Opossum and Kangaroo.

VII. Carnivora. *Flesh-eaters*, as the Lion, Tiger, Dog, and Bat.

VIII. Quadrumana. *Four-handed*, as the Monkeys and Apes.

What are Cetacians? Ruminants? Pachydermata? Edentata? Rodentia? Marsupialia? Carnivora? Quadrumana?

296. General account of Fossil Quadrupeds.—Before proceeding to the description of particular fossils, we will give a summary of what is known with respect to the number of species discovered in the fossil state, and the methods employed to distinguish the remains of one animal from another, merely by the examination of their detached bones. This method is due entirely to the zeal, patience, and learning of the celebrated Baron Cuvier, of Paris, the founder of Palæontology.

All the organic remains of this class have been found in diluvial and tertiary formations, being those considered the most recent in which fossils occur. Since the time of Cuvier, a considerable number of extinct species have been brought to light in various parts of the world; and the catalogue is every year increasing, and probably will continue to do so for centuries to come; for, as yet, only a small part of the earth has been examined where such relics may be expected to occur.

297. *Quadrupeds determined by Cuvier.*—The number of quadrupeds, the classes and orders of which have been determined by Cuvier, solely by the examination of their fossil remains, amount to about one hundred and fifty. Of these, ninety species were before entirely unknown to naturalists, and are therefore considered extinct, their entire races having perished at the period when their bones, generally found in the most recent strata, were there buried. Ten or twelve of the other species, so nearly resemble those at present known, that little doubt is entertained of their identity; while many of those which remain, exclusive of the ninety extinct races, present kindred features to known species; but in some instances, the want of a sufficient number of perfect specimens, and in others, some defect in an essential part, have prevented comparisons being made with sufficient accuracy, to remove all doubt; and, therefore, it is still uncertain whether any living examples of their races exist or not.

Of the ninety unknown species, about thirty belong to genera still living, and the remaining sixty, to genera entirely unknown; presenting to the naturalist the remains

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Who was the founder of Palæontology? In what strata are fossil quadrupeds exclusively found? What number of quadrupeds were determined by Cuvier, by their fossil bones? How many species were unknown, and how many still living?

of so many races of animals, which once prowled or ruminated where, at the present time, not an individual of their whole tribes is known.

With respect to the classes and orders to which these animals belonged, about one-fourth of the one hundred and fifty species, were oviparous (egg-laying) cold-blooded reptiles, as the alligator, lizard, and tortoise. The remainder were mammiferous animals, as the elephant, deer, mastodon, and hare. Of the latter, more than one-half were non-ruminant, hoofed quadrupeds, as the horse, tapir, and hog.

298. *Proportions of the different genera.*—From these facts, thus developed, concerning the animals of the primitive or ancient world, it might, perhaps, be supposed that some theory could be formed, with respect to the proportions of the different genera, which then inhabited the earth; and by a comparison of them with those now existing, we should be enabled to arrive at some conclusions with regard to the difference. But it would be premature to form any hypothesis on this subject at present, since we know not but there are still hundreds of extinct species, or even genera, still undiscovered; and there possibly may be existing species of some magnitude, still unknown to naturalists, though there is little expectation of finding any large quadrupeds in regions of the earth which remain unexplored. With respect to marine animals, there is more probability that there remain some, even of considerable size, which naturalists have, as yet, had no opportunity of examining; for there are yet unknown seas and coasts to be explored.

299. *Extinct species, not varieties of the recent.*—Cuvier has proved, as we shall see directly, that the extinct species of quadrupeds are not *varieties* of those now in existence, but that there exist distinct specific differences between them. "A species comprises all the individuals which descend from one another, or from common parents, and those which resemble each other, as much as they resemble themselves." Hence, the *varieties* of a species are the result merely of such changes as take place in the color, size, and fineness of the fur of animals;

Is it probable that more extinct species will be discovered? Is it probable that all existing species are known? How does a species vary from a variety?

and which may be caused by a difference of climate, of food, or the domestication of the species; these varieties may, therefore, produce the exact likenesses of their parents. For example, the dog is a genus; the pointer is one species and the greyhound another. Now, every one knows, who is conversant with dogs, that pointers may differ from each other in color, size, and shape; and even from the same parents, it is seldom that two precisely similar can be found. These are varieties of the pointer, but the species is not changed; for their instincts, habits, and general appearance, are the same with those of their parents. The same variations may be observed in the greyhound, and, indeed, in all other species of dogs. But if the races are kept distinct, there are no circumstances of climate, or food, or training, that will change the greyhound into the pointer, or the contrary. The species are, therefore, entirely distinct and unchangeable.

"The fox and the wolf," says Cuvier, "inhabit every country, from the icy to the torrid zone; they experience, in this immense interval, every change of climate and condition, and yet the species have suffered no other change than a slight variation in the beauty of their fur." The same accurate observer compared the skulls of foxes from the north of Europe, and from Egypt, with those of France, but found no appreciable difference. Hence, we learn that the species of animals never change by time, circumstances, or condition, which some have argued to be the case.

300. *Although species never change, animals may acquire new instincts, which become hereditary.*—The young pointer, of good blood, is as *stanch*, as sportsmen call it, when first taken to the field, as ever afterwards; that is, he will stand, and point at the game with his nose, without ever having before smelled a bird, or seen any of his race exercise this wonderful instinct. On the contrary, a common whelp, under the same circumstances, will instantly rush upon, and *flush* the game, without hesitation. Now, at what period, and by what nation, dogs were first trained to stand upon game, we do not pretend to know; nor will we venture to say that this species did not originally pos-

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Do the same races ever produce new species? Do the species of animals ever change? What is said of acquired instinct? What proof does the pointer furnish?

sess this instinct, now so highly valued by man, in all parts of the world. But it is most probable that it has been acquired through the agency of man, since it certainly could have been of no use to these animals in their wild state; and in further proof that it is an "*acquired instinct*," it is well known to sportsmen, that dogs deteriorate when not employed; and that the descendants from parents of good blood, in which this faculty has never been exercised, are often worthless in the field, having little or no appetency to display the peculiarity of their race; and it is asserted that this instinct is lost entirely, after a few generations in which it is not exercised. Hence, one of the first inquiries which a sportsman makes, when about to purchase a pointer, is, whether his parents were stanch and well-broke animals.

301. *The Retriever, another instance of similar faculty.*—The instinct of the retriever, is, perhaps, a still more striking instance of a faculty, peculiar to a race of animals; for it may, perhaps, be said of the pointer, that his peculiarity is only a modification of a habit acquired in the wild state, of standing for an instant, in order to gather strength, or to make a more sure leap upon his game; but the business of the retriever is, to bring the wounded bird, and lay it at the feet of his master; and this faculty the race inherits, as the pointer does that of standing upon the bird which he has perhaps never seen, and which he knows, only by the smell, lies a few yards in front of him. In proof of this instinct in the retriever dog, it is said that the celebrated French physiologist, M. Majendie, having learned that there was a race of dogs in England, which stopped, and brought game of their own accord, procured a pair; and having obtained a young animal from them, kept it constantly under his own care, until he should have an opportunity of assuring himself that, without receiving instruction, it would perform the duty peculiar to its race, and that on the first day it was taken to the field, it brought back game, with all the readiness of dogs which had grown old in the exercise of this instinct. Similar peculiarities exist in the bloodhound, the foxhound, the shepherd's-dog, and in the dogs of St. Bernard, which, from time immemorial, have been celebrated all over the world, for their instinct, in detecting and assisting persons buried in the snow.

302. Now, how far it is possible to convert one of these races into the other, that is, to train the foxhound to point a bird, or the pointer to follow the fox, we know not. But whoever has had an opportunity of noticing the facts, knows that the foxhound takes no notice of birds, nor can the pointer be made to pay the least regard to the scent of a fox, however strong; and that if we mix these races, the result becomes utterly useless, either for the field or the chase.

These facts go to prove that no such thing exists as new species, formed of varieties, as some French savans have endeavored to show; for if the useless products above mentioned be continued, they never would form new species, but would remain mongrels, or varieties of the two races from which they originated; and if either side predominated, the result would be, either a foxhound or a pointer. Hence, we may come to the conclusion, that the fossil remains of animals, which present distinctive characters, differing from species or orders now existing, never could have been the originals, by change of climate, or circumstances, gradually changed to the present species; but that the distinctive traits of these ancient races, would have remained the same, had they lived and flourished to the present time.

MEANS OF DISTINGUISHING FOSSIL BONES.

303. Before proceeding to the description of individual fossil species, it is necessary, for the information of the student, to describe the method by which naturalists have been enabled, by examining their petrified remains, to distinguish these unknown animals from each other, and from those now living; and to reconstruct not only entire skeletons, even where many bones are wanting, but to clothe the creature with a new skin, and to give him a snout, a proboscis, or other fleshy organ, where the stony frame indicates that such parts were possessed by the original animal. All this has been repeatedly done by the acute and laborious Baron Cuvier, who, we repeat, was the father of this science; and who, by constant devotion to this his favorite pursuit, brought it to a degree of per-

What is said about the change of species? Would the fossil animals have changed, had their races lived to this day? What is said of the reconstruction of animals?

fection, to which little or nothing has been added by his successors.

The principle on which this discrimination is founded, is the peculiar and perfect organization of each species, so that one part is invariably and exactly adapted to another, and is as clearly indicated by it, as a neck indicates a head. Each animal constitutes a whole, one systematic cycle, whose parts are in mutual correspondence, and concur to the same definite action, by a reciprocal reaction. None of these parts can change without symmetrical change in the others; and hence each, taken by itself, indicates, and gives form to all the others.

304. *Carnivorous animals.*—Thus, if the organs of an animal are so constituted as to digest only raw flesh, its jaws must be constructed for devouring its prey; its claws for seizing and tearing; its teeth for cutting and dividing; the entire system of its organs of motion, for pursuing and overtaking it; its organs of sense, for descrying it at a distance; and even its brain must be qualified for exercising the instinct of self-concealment, and the art to ensnare its victim. Such is the general condition of the carnivorous temperament, every animal endowed with which, must combine them all, for otherwise its race could not subsist.

For the jaw to seize its prey, there must be a certain kind of articulation, which gives prominence, as in the lion and cat, to the cheeks, and fits the bones to receive the insertion of strong muscles; for without these, any such articulation would be useless. To enable the animal to carry off its prey, there must be a certain degree of strength in the muscles of the neck, and hence results a determinate form in the vertebra, and the hind part of the head, to which these muscles are attached.

Whoever will compare the bones of a rabbit with those of a cat, will see how these parts differ; and if he will study the subject, he will soon convince himself why the bones of the rabbit, independently of the teeth, could not have been fitted for the purposes of a rapacious animal.

For the claws to seize the prey, there must be a certain mobility in the talons, and a certain degree of strength

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How does it appear that the bones of a cat, are better fitted than those of a rabbit, for prowling animals?

in the toe-joints, which the rabbit does not possess; and hence there must be a corresponding distribution of the muscles and tendons, so that lightness and power may be combined, as may be seen in the cat. The shoulder-bones in such animals must have great firmness, otherwise the legs will not be fitted for the uses of the claws; and this firmness of bone is thus prepared to receive the insertion of strong muscles, by which the required power is given.

It is unnecessary to show how the other parts of a prowling animal are adapted to each other, so that the whole machinery of bones, muscles, joints and tendons, all combine to the accomplishment of the same end. The parts of any animal are indeed "a collection of wonders;" and he who does not behold in them the traces of Infinite Wisdom and design, must either want understanding or sight.

In a word, says Cuvier, the formation of a tooth indicates the structure of the jaw, and its kind of articulation; the structure of the shoulder-bone, shows the form of the feet, just as the equation of a curve involves all its properties; and as, by assuming such property separately, as the base of a particular equation, we should so produce both the ordinary equation, and all its properties; so the nails and shoulder-blade, indicate the articulation of the jaw; the thigh-bone, and the other bones, taken separately, give the form of the tooth, or are given by it in their turn.

305. *How species are distinguished.*—Since the mechanism of every animal involves certain fixed and invariable principles and proportions, which belong to the whole race, by ascertaining what these are, we can readily distinguish one tribe or species from another, though the difference may be ever so slight. To the common observer, the entire skeleton of a horse would be readily distinguished from that of an ox, by the size and proportion of the whole; and by comparing the thigh-bones of the two animals, he would readily distinguish them, and thus take one step in comparative anatomy; for now he would be able to distinguish a horse from an ox, merely by inspecting a single bone.

It is plain, from this single example, that by the constant examination of the bones of different classes, genera and

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What is said of wisdom and design in the construction of animals?

species of animals, the observer might attain great perfection in this art; so that even without comparison, he would be able to decide in an instant, whether a given bone belonged to any living genera of animals or not; and by closer care and comparison, to point out those differences which distinguish the osteology of one species from that of another.

DO ANY OF THE FOSSIL ANIMALS STILL EXIST.

306. The Mastodon, or Mammoth, whose bones have been found in various places in this country, is an example of an extinct species. If an animal of such magnitude was still living in any part of this country, there can be no doubt but a knowledge of the fact would long since have been communicated to the whole civilized world. Our adventurers, or exploring parties, have crossed nearly every degree of latitude and longitude on the American continent, and are now more or less acquainted with nearly every Indian tribe; and yet nothing, except some vague traditions, has ever transpired concerning any animal larger than the Bison or Moose. No doubt can exist, therefore, that the entire race of the Mastodon has long since been extinct. Nor can there be any question, that this animal is a distinct species from the elephant, which, in its osteology, it more nearly resembled than any other known species, whether fossil or recent. This is proved by the size and form of its bones, especially its tusks and grinders, many of which have been compared with those of the elephant now living, and the specific differences pointed out.

But it has been suggested by several naturalists, that more or less of the unknown fossil species, of the second or third magnitude, might now exist in parts of the earth still unexplored. On this point, we quote Baron Cuvier:

307. "If," says he, "we examine what species of quadrupeds have recently been found, and in what circumstances they have been discovered, we shall see that there is but little hope of ever finding those that we have only seen as fossils. Islands of moderate extent, situated at a distance from extensive continents, have very few quadrupeds, and these always of small size. When they have

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Why is it supposed that the race of the Mastodon is extinct? What is said of large animals existing on islands?

large ones, it is because they have been brought from elsewhere. Bouganville and Cook found only dogs and hogs in the South Sea islands; and the largest species in the West Indies, was the agouti, (a species of hare.) In fact, only large territories, such as Asia, Africa, America, and New Holland, have large quadrupeds, and, generally speaking, peculiar to themselves."

208. *Animals known to the ancients.*—The ancients were acquainted with all the animals now known, (of any considerable size,) except such as have been discovered in America and New Holland. The Greeks were acquainted with the elephant, and the double and single-horned rhinoceros, and both these animals were common at Rome. Heliogabalus exhibited the hippopotamus and giraffe, or camelopard; the former, it is believed, has not been since seen in Europe. The two species of camel, one of which is now called the *dromedary*, were known to the Romans in the time of Julius Cæsar. The buffalo, the wild, ox the ox without horns, and the little ox, no larger than the goat; the sheep with the great tail, and the great sheep of India, were all known to the ancients, for they have left descriptions of them.

The Romans exhibited lions and tigers by the hundred; they also showed hyenas, and even the crocodile of the Nile. Even the Zebra also, which is found only in Southern Africa, graced their shows, and they were acquainted with the most remarkable species of the Ape-tribe. These facts show, that the ancients were acquainted with all the quadrupeds of any consequence in the old world, and that naturalists, in later times, although they have reduced Zoology to a science, and have described many smaller animals, which were probably unknown to the Greeks and Romans, have still failed to discover any Mammalia of consequence, with the exception of those of America and New Holland.

It is quite improbable, therefore, that any of the larger quadrupeds, or even amphibious animals, now considered extinct, except perhaps some small ones of the latter kind, are still any where in existence; and since it has been shown that they are distinct species, and not varieties of

What animals are enumerated with which the ancients were acquainted? What is the conclusion with respect to the existence of any of the fossil animals?

those now known, there is no doubt but these entire races have been destroyed by some violent catastrophe.

309. *When, and by what means, did these races perish?*— At what period of the world these ancient races of quadrupeds were utterly swept from the face of the earth, and so many of them buried at various depths, under what now are solid rocks, and by what means such a catastrophe was effected, are highly important questions in geology; but to these little else than hypothetical answers have been, or can be given. Many geological writers of the first class, and especially Dr. Buckland, have attributed this destructive calamity to the deluge, described in the Scriptures, and especially with reference to the more recent species, or those having examples still existing. The remains which occur in what geologists have been wont to call *Diluvial* formations, as being the effects of the Noachian flood, and particularly those found in various caves, are considered of recent origin, when compared with the fossils of the Tertiary strata. The latter formations no geological writer believes to have been the effects of any sudden or temporary diluvium, since the number, and often the depths of the strata, are evidence that these rocks are due to often-repeated irruptions of water, sometimes at long intervals of time from each other. Besides, these formations often contain vast quantities of sea-shells, with all their sharp and prominent points remaining perfect, clearly showing that they were not swept together by floods, which would have denuded these delicate angles; but, on the contrary, that they perished, and were buried where they are now found, apparently by gradual and gentle depositions of sand or mud suspended in still water. Such are the strata in which are found the remains of quadrupeds, intermingled, not only with marine shells, but also with the relics of fish and reptiles; the entire phenomena, to all appearance, proving that these formations were made in deep sea-water, though at the present day they may be scores, or even hundreds of miles from the ocean. That these accumulations, thus formed in the sea, have become dry land by the elevating power of volcanic forces, will be shown when we come to speak of volcanoes and their effects.

Which are the most ancient, the diluvial or tertiary fossils? What are the facts to prove that the tertiary strata were formed under the sea?

310. *The fossil bones of man not found.*—In addition to the above objections to the probability that the extinct species of Mammalia owe their final exit to the general deluge, is the fact, that at that period, the earth contained millions of human beings. the remains of not one of whom have yet been discovered in any of the accumulations attributed to its effects. We must therefore conclude that these extinct races, the remains of which are found imbedded in strata, lived before the creation of our race, and perished by some catastrophe, of which our sacred records contain no history. Nor does this supposition present any incompatibility with the Mosaic account of the creation, since it will be seen hereafter, that from "the beginning," when the heavens and the earth were created, down to the creation of man, the geologist may claim an indefinite period of time, and more than this we think no reasonable philosopher would desire for the formation and growth of the most ancient strata.

In many instances, the appearances are such as to give grounds for the supposition that the whole of each extinct family perished at about the same period, their remains being found in similar strata, and apparently formed at the same periods of time, though existing in various and distant parts of the earth from each other. Thus, the trilobites occur in similar formations, wherever they are found, indicating that the race perished at the same period, and while the same strata were forming in various parts of the earth. The same is true with respect to the races of extinct quadrupeds.

311. THE DODO.—It is probable that some races, or at least one species certainly, has perished gradually, and without any known catastrophe. This is the Dodo, a large bird, figured and described by many former naturalists. It appears that during the early voyages of the Dutch navigators to the East Indies, this bird existed in various places, and particularly on the island of Mauritius, where it was not uncommon. Linnæus described it under the name of *Didus*. Brooks, in his *Natural History*, London, 1783, says, the Dodo is a large heavy bird, with short legs, great black eyes, large head, covered with a membrane, resem-

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What are the objections to fossils being buried by the deluge? Have the bones of man ever been found in the fossil state? What is said of the extinction of the Dodo?

bling a hood, or cowl; bill, bluish white, of great length, sharp and hooked at the end; body covered with feathers. much like of those of an ostrich; legs yellow, with four strong toes. He further states, that it is a simple bird, swallows stones, and is easily taken. Its flesh is good and wholesome, and three or four are enough to dine one hundred sailors.

Mr. Lyell says, that many naturalists gave figures of the Dodo, after the commencement of the seventeenth century, and that there is a painting of the bird in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which, ornithologists are agreed, cannot belong to any other bird.

That this race has become entirely extinct, appears from the fact, that after the most active search in the countries where it was once known to exist, made repeatedly during the last century, no traces of such a bird can be found; and Cuvier (*Animal Kingdom*) says, that the Dodo has completely disappeared, nothing remaining of it at present, but a foot in the British Museum, and a head in the Ashmolean Museum at Oxford.

312. Animals Extirpated.—This, it is believed, is the only instance known to naturalists, where any species of animal has become extinct within the historical era. It is, however, true, that the increase of the human species has, in various countries, entirely extirpated whole races of animals, from districts where formerly they were abundant. Thus, the beaver, once a native of Scotland and Ireland, where it was eagerly sought after for its fur, became extinct in those countries during the twelfth century; and the wolf, formerly so much dreaded in Ireland, has for more than a century been entirely unknown in that country. The bear and wild boar, also once beasts for the chase of the royal hunters of Wales, have several centuries since entirely disappeared from that country.

In our own country, many animals, well known to our forefathers, have been entirely driven from the more populous districts and states. The bear, deer, panther, the wild turkey, and perhaps the elk, were all abundant in most parts of New England, only a century, or, at most, a

What animals are said to have been extirpated in Scotland and Ireland? What is said of the expulsion of animals from New England?

century and a half ago. Now, with the exception of the northern districts, where a few of these species are found, they are, in the wild state, totally unknown.

313. THE BISON.—And with respect to the Bison, where formerly, and even within twenty-five years, travelers inform us their numbers were so great, that the eye could not at the same time reach the beginning and end of the drove, it is now said that few remain; and that in large districts of country, where, within the memory of the Aborigines, these animals were abundant, not one at the present day is to be found. This, it is said, is not owing to their change of location, but in part to the improvidence of the natives in destroying, with their rifles, thousands, of which they make use only of their skins in barter with the whites, and in part to the eagerness of the hunters of the fur companies to possess themselves of their flesh for food, and their robes for sale. It is therefore the opinion of well-informed persons on this subject, that at the present rate of destruction, which is constantly increasing in proportion as civilization, or rather the arts of destruction, advance in that country, the time is not very far distant, perhaps even within the present century, when not a wild Bison will be found within the immense territories now known to civilized man. If these predictions are true, the time will come when the Bison, if not domesticated, will only be known to naturalists as an extinct, or fossil species.

CHAPTER XXV.

INDIVIDUAL FOSSILS.

314. HAVING given a list of the orders of the Class MAMMALIA, (295,) which are found in the fossil state, and having given a general account of fossil quadrupeds (296); also, the number of species determined by Cuvier (297); having shown that the extinct species are not varieties of those now existing, and pointed out the method of discriminating fossil bones (303); also, how species are distinguished; and having examined the question whether any

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What is said of the destruction of the Bison?

unknown quadrupeds still exist (306); and shown what animals were known to the ancients (308); having also examined the question, by what means did these races perish? (309); and stated that fossil bones of our own race have never been detected (310); and finally, shown that one species, the Dodo, had become extinct within the present age, and that the Bison in all probability would ultimately be known only as a fossil species, we now proceed to the examination and description of individual fossil mammalians.

315. CETACEA, (*the whale family.*)—There are many species of this genus, measuring from fifteen or twenty, to sixty or seventy feet in length. The family are inhabitants of all climates, from the tropics to the arctic ocean. The northern Pacific is at present the great whaling ground, where hundreds of ships, of different nations, are constantly employed in their destruction. In 1846 there were, from the United States alone, seven hundred and twenty-eight vessels, and upwards of twenty thousand seamen employed in this fishery; and still intelligent captains inform us, that although these monsters of the deep often change their ground to avoid their persecutors, their numbers do not appear to diminish.

316. Although there is no danger that this family will become extinct, at least during many centuries, yet there are perhaps no large animals, at the present day, so liable to become fossils, or at least to be entombed in alluvial accumulations, as these; being, it is well known, constantly exposed, during storms, to be stranded, especially when they happen to stray into unknown waters.

During easterly storms many such instances have happened, within the memory of man, on our coasts; and Mr. Lyell records a list of such accidents on the shores of Britain. These large creatures *draw*, as the sailors say, a considerable depth of water, and when strangers to the coast, or out of their reckoning, are liable to run into shallow places, which, happening at high tide, when the ebb commences, they become helpless, not merely because they are out of the water, (since, as we have already seen, they are air-breathing animals,) but chiefly because their new

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What are the Cetacea? What are the sizes of this family? What climates do they inhabit? Where are they chiefly found? What number of ships and sailors? What is said of the stranding of whales?

and fearful situation induces such violent struggles, as to bruise the flesh in a manner which, after a while, perhaps several days, produces their destruction. If this misfortune happens in the vicinity of any inhabited coast, the poor animal is not allowed to struggle long, but is soon dispatched for his oil, and the bones left to be buried in the sand

317. In most instances, the remains of whales are found in alluvial accumulations near the sea shore, but some examples are known where these bones are elevated considerably above the level of the water. Thus, on the bank of the river Forth, in Scotland, lies the skeleton of a whale, seventy-three feet long, imbedded in clay, twenty feet above the highest tide. From circumstances with respect to a Roman camp, which was once near the spot, it is suspected that this animal was stranded before the time of the Christian era, but by what means the bones were elevated, no one has offered to explain. On the east end of Long Island, it is said that the remains of a whale, at a considerable distance from the shore, though but little above high-water, were to be seen within a few years. The accumulation of sand, by the action of the waters of the Atlantic, readily accounts for its present distance from the shore.

II. FOSSIL RUMINANTS.

318. The fossil remains of the *cud-chewers*, as the deer and elk, are quite numerous in the alluvial deposits and in caves, in many parts of the world. The following list, although not all ruminants, is stated by Mr. Lyell to have been found in a marl-pit in Farfarshire, in Scotland. They all belong to species which now inhabit, or are known to be indigenous in Scotland. The skeletons of several hundreds have been procured within the last century, from five or six small lakes, where shell marl is worked. Those of the stag (*Cervus elephas*) are most numerous; and if the others be arranged in the order of their relative abundance, they will follow nearly thus: the *ox*, the *boar*, the *horse*, the *sheep*, the *dog*, the *hare*, the *fox*, the *wolf*, and the *cat*.

By what means such an assemblage of animals, so widely differing from each other, came together at this spot, it is difficult to imagine. In the greater part of these lake

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What is said of the remains of a whale in Scotland, and on Long Island? What are the ruminants?

deposits, says Mr. Lyell, there are no signs of floods; and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds, could have crossed by swimming from one to the other.

319. Irish Elk.—But the most celebrated fossil of this family, is that known under the name of the great Irish Elk, the bones of which have been found in immense quantities in the superficial marl-pits of Ireland, in the Isle of Man, and sometimes in England. A skeleton, almost entire, discovered in the Isle of Man, in a pit of shell marl, at the depth of twenty feet, is six feet high, nine feet long, and to the tip of one of the antlers, nine and a half feet. Some of the antlers are of such immense size, that from tip to tip, as they stood on the animal, they measured fourteen feet.

III. PACHYDERMATA.

320. These, as already explained, are the *thick-skinned* animals, as the elephants and mastodons. The genera of this order, determined by Cuvier, are the following, viz: Elephant, Mastodon, Rhinoceros, Hippopotamus, Tapir, Hog, Horse, Daman, Pecaris, Phacocheres, Anoplotherium, Palæotherium, and Elasmotherium. These are termed non-ruminant hoofed quadrupeds.

Genus Elephant.—Of this genus there are three distinct species, two of which, the Indian and African, still exist, the third having been found only in the fossil state.

1. The Indian Elephant is found on both sides of the Ganges, and in Borneo, Java, Sumatra, and other Indian islands. This species is characterized by an oblong skull, concave front, small ears, with grinding teeth marked by ribands, or plate-lines, which are waved.

2. The African species is found near the Cape of Good Hope, Senegal, and Guinea. It has a rounded skull, large ears, and grinders with lozenge-shaped lines on their crowns.

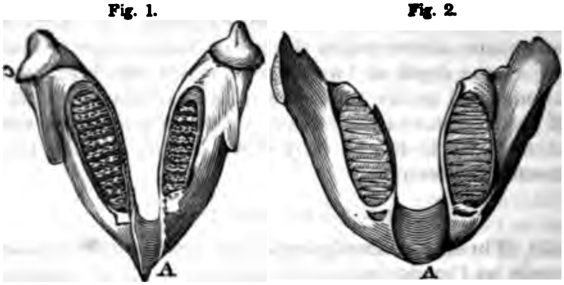
3. Fossil, or primeval Elephant, (*Elephas primigenius.*)—This is the mammoth of the Russians. It has an oblong skull, concave front, very long bony sockets for its tusks; lower jaw-bone obtuse, grinders parallel, and marked with nearly parallel and little waved ribands on the crown.

How large was the fossil Elk of Ireland? What animals belonged to the thick-skinned order? How many species of the Elephant? Where are they found?

The student in comparative anatomy will observe by what differences of osseous form, or structure, one species is separated from another. Thus, in the above descriptions, the fossil species appear to differ from the living, chiefly by a greater projection of the sockets of the tusks, and a small variation in the markings of the grinders and form of the jaw.

LIGN. 65.

Fig. 1. Fig. 2.



Elephants' jaws.

321. This difference will be best observed, however, by comparing the figures of the grinders, as shown by *Lign.* 65, where that on the left hand, *Fig.* 1, represents the under jaw of the living Indian species, and that on the right, *Fig.* 2, the corresponding part of the fossil elephant. The sides of that of the living species, converge nearly together at the lower part, and it has a projecting point at *A*, furrowed with a long narrow canal. The teeth also converge, and the inequalities, or ribands on the crowns, are waving lines, running obliquely crosswise. The teeth in the fossil jaw stand nearly parallel to each other, and the canal in front is much shorter and wider, and without the projecting point. The ribands, also, in these are not oblique, as in the living, but run transversely across the crowns.

In the two living species, the sockets of the tusks (*alveoli*) do not extend further down than the end of the lower iaw, so that the chin has room to protrude between the tusks in a pointed projection. But in the fossil head, on account of the great length of the tusk sockets, the lower iaw has the appearance of having been truncated, or

What are the chief differences between the living and fossil species?

blunted at its lower end, so as to admit of its being closed on the upper one, by means of which the lips come together in the act of mastication, contrary to what takes place in the living species. These, with other differences, in the osteology of fossil and living elephants, which need not here be detailed, make it certain that the fossil species belonged to a race of animals, none of which are now in existence.

322. *Teeth of the same species alike.*—In all animals of the same species, and ages, the teeth are precisely alike in form and number, and therefore whenever we find merely a similarity, and not an identity, in these respects, we may know that the species are different, though the genus may be the same. The form of the jaw also differs, more or less, with that of the teeth.

323. *The fossil most nearly resembled the Indian Elephant.*—The fossil elephant more nearly resembled the Indian, than the African species, but differed from both in the form and markings of the grinders, as above shown; also, in the great size of the tusks, and especially in the projection of the tusk sockets, as shown by *Lign.* 66, *a.* This last peculiarity must have very much modified the figure and organization of the proboscis, and given to this elephant a physiognomy, differing much more from the other species, than might be inferred from the small difference in the general structure. Its size was about that of the Indian elephant, say from ten to thirteen, and even sometimes sixteen feet in height. The grinders of this species are ten or twelve inches long, and have twenty-four ribands, or enameled plates, raised above the surface, and crossing their crowns.

Great number of fossil Elephants' remains.—The bones of fossil elephants have been found in many different countries, and sometimes at several localities in the same districts. In nearly every part of Siberia, as high as latitude 65°, wherever a river happens to undermine its banks, the bones of these animals are discovered. In some places, they have been found in such abundance, that large quantities have been transported to other countries, as a valuable article of commerce. Indeed, it is said, that at the

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What difference can you show between the jaw-bone of the recent and fossil elephant? What difference in their grinders? What was the size of the fossil elephant? How large were the grinders in this species?

present day, a considerable portion of the ivory employed in the arts, is of the fossil variety. Of course, these are not petrified.

324. *Found in the vale of the Arno.*—In the valley of the Arno, near Florence, in Italy, so great was the accumulation of these bones, that it is said the inhabitants formerly used them in making fences between their fields. These bones, tusks, and grinders, are also found in France, in Germany, in nearly every part of Italy, where a morass, marsh, or gravel-pit is opened; also, in the Netherlands, Holland, Russia, Bohemia, in many parts of England, and in the northern parts of North America. A remarkable locality of these relics was many years since discovered at Thiede, near Wolfenbutel, in Germany, where eleven tusks and thirty grinders were disinterred, within a short distance of each other. One of these tusks was fourteen feet eight inches long, and bent into a perfect semi-circle. In nearly every gravel-pit around London, the bones of this species are found. They have also been discovered in many other localities, in various parts of Great Britain.

325. These discoveries prove, beyond doubt, that this race of animals must, at some former period of the world, have been exceedingly numerous; and that they inhabited nearly every portion of the earth. At present, this genus is found in hot, or temperate regions only. Whether the temperature of the earth differed at the time when these animals perished, from what it now is, can only be inferred from many circumstances respecting plants, as well as animals; and from all of which, several geological writers have concluded that our terrestrial abode, more than one half of which is now clothed in ice for at least half the year, once, every where enjoyed a tropical climate; and that organic nature, instead of lying dormant during a considerable portion of the year, flourished perpetually, enjoying a perennial spring. (*See change of climate.*)

326. *Formations in which these bones occur.*—The mammalia, though sometimes found in strata mixed with sea-shells, being probably drifted into the sea by land-floods, are more commonly disinterred from the most recent formations, as the alluvial or diluvial accumulations, or what

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What is said of fossil ivory? How widely are the remains of the fossil elephant found? What do these discoveries prove? What are the formations in which fossil elephants occur?

some writers at present call *drift*. In many instances, the localities of these bones, were evidently once ponds, or lakes, or perhaps peat-bogs, into which the animals were driven by floods, or venturing too far, perhaps, for drink, sunk into the mud, and there perished. Some of these remains are also found in tertiary limestone strata, of the more recent epochs; but no quadrupeds of this class have occurred in the more ancient formations with the early shells or plants.

327. *Elephant preserved in ice.*—In the summer of 1798, a fisherman discovered, at the mouth of the river Lena, in Siberia, a dark-colored mass projecting from the ice, which attracted his curiosity; but being far above his reach, he could not determine its nature. The next year, going to the same place, he found that the mass had been partly disengaged by the melting of the ice around it; but still the man was unable to decide what it might be, as it was more than one hundred feet above him, and inaccessible to his approach. The man continued to pay yearly visits to the spot, but was unable to determine what he had discovered, until 1803, during the summer of which, it fell down on a sand beach of the Arctic ocean, so as to be examined.

The fisherman now obtained a prize; for having detached the two tusks, he removed and sold them for fifty roubles. The flesh of the huge animal had undergone no decomposition, having been almost entirely surrounded by the frozen mass, until nearly the time of its fall.

The fisherman having made known his discovery, numerous persons visited the spot from curiosity; but it does not appear that any one who appreciated such a phenomenon, or who was disposed to report the circumstances to the world, saw it until 1806, three years after it had fallen, when Prof. Adams, of St. Petersburg, went to the spot. It still remained on the sand, but the body was then much mutilated, the people in the vicinity having carried away large quantities of the flesh to feed their dogs; nor had the white bears failed to regale their appetites on this antediluvian delicacy. The skeleton, however, remained quite entire, with the exception of one of the legs and the tusks. The head remained covered by the skin, and the pupils of

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What circumstances are stated of an elephant preserved in ice?

the eyes were still to be distinguished. The brain, on opening the skull, was found not quite filling its cavity, being somewhat dried. One of the ears was well preserved, still retaining its form, with the long hair which grew upon it. This animal was a male, and had a mane of considerable length, still on the neck.

The skin, when detached, was so heavy, that ten men removed it with difficulty. More than thirty pounds of hair and bristles of this animal, were gathered from the beach, where it had been left and trampled upon by the white bears, when tearing and devouring the flesh. The hair was of three kinds, viz: stiff black bristles, a foot long, coarse hair, of a reddish color, and a woolly covering next the skin, of the same color.

The skeleton of this elephant was taken to St. Petersburg, and the tusks having been procured, the whole was set up in the Museum of that city, where it remains to the present time. The head and tusks of this animal are represented by *Lign.* 66, as drawn up by Mr. Stokes, who also gives the description as above detailed, in the *Ed. Quar. Journal*, First Series, p. 96.

LIGN. 66.

Elephant's head.

328. *Size and form of the tusks.*—It will be observed that these tusks are of enormous length, and that they form nearly a circle, differing greatly, in form and size, from those of the elephant of the present day. The pro-

How do the tusks of the fossil differ from those of the living elephant?

jection of the tusk sockets, marked *a*, may also be observed, and which, as already noticed, are peculiar to this species.

This skeleton is about 9½ feet high and 16½ feet long; and when it is considered how much the cartilages, flesh, and skin, added to his height and dimensions, it must be obvious that this animal was of enormous magnitude.

329. *Rhinoceros preserved in ice.*—The hair with which the above-described elephant was covered, would seem to indicate that it was fitted for a cold climate; and in addition to this instance, Prof. Pallas records the fact, that on the bank of one of the tributaries of the Lena, there was discovered an entire Rhinoceros, well preserved, and covered with hair, which was particularly long about the feet, the whole forming a warm covering, like that of an animal prepared for a cold climate.

330. *Different species fitted for hot and cold climates.*—From the above circumstances, it has been argued by some naturalists, that the bones of the great quadrupeds found in all climates, and of genera which now inhabit only hot ones, were of species so different from the latter, that they were fitted for the cold climates where their remains are found; and hence, that it is unnecessary to suppose that they were either transported from warmer climates, or that the climates where their bones are now found, have suffered any change. But there is a difficulty in this theory, since, if Siberia was never warmer than at present, it is impossible to believe that it should have ever produced a quantity of vegetation, sufficient to have supported such herds of enormous animals, as their bones now indicate, even during the summer, and much less during the eight winter months of that climate.

331. Genus Mastodon.—The name comes from two words, which signify a "little hill" and a "tooth," in allusion to the prominences or tubercles, which the crowns of their grinders present. The form of this crown is similar to that of carnivorous animals; and hence, when little was known of fossil bones, it was supposed that the Mastodon had been a flesh-eater, an error fully refuted by Cuvier.

The form of the Mastodon's grinder is represented by *Lign.* 67, the tubercles, or hilly points, being a little worn

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What is the size of this skeleton What theory has been formed, with respect to the hairy covering of the elephant and rhinoceros? What does Mastodon signify?

by use. It is here seen one-fourth the natural size, and is from a specimen in the king's cabinet in Paris. The difference between this and the elephant's grinder, will instantly be seen. The number of such teeth in the Mastodon was four in each jaw.

LXCX. 67.

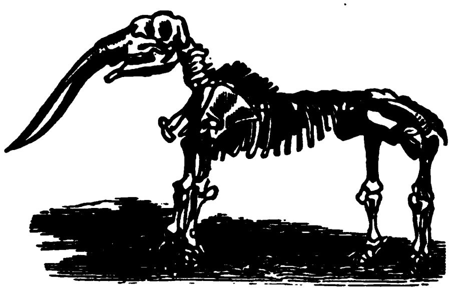
Mastodon's grinder.

Number of species.—The entire genus mastodon, popularly called *mammoth*, is extinct; but from their bones, Baron Cuvier determined six species, viz: 1. The great Mastodon. 2. The Mastodon with narrow teeth. 3. The Mastodon of the Cordilleras. 4. The Mastodon of Humboldt. 5. The small Mastodon. 6. The Tapiroid Mastodon. To these Mr. Clift has added two others, making, in the whole, eight species. It appears that some, if not all these species, were widely different from each other, so that in most cases the bones of one species only are found in the same country.

The largest animal of this family has been found only in North America, viz: the *Mastodon maximus*, but no other species has occurred in this country. It appears from its remains, that this species was common in all the south and west parts of the United States; its bones having been found in various places in Kentucky, Ohio, Alabama, New York, and, it is said, as far east as Berlin, in Connecticut. The best preserved, or most perfect skeleton, except that found at Newburgh, is that set up in Peale's Museum,

How many species of Mastodon? Where found?

Philadelphia, which is 11 feet high and 15 feet long. This was found in Orange county, New York. The relics of the other species are found in Europe, especially Germany and Italy; also, in South America and in India.



Mastodon Maximus.

MASTODON MAXIMUS FROM NEWBURGH.—A larger and more perfect skeleton of the *Mastodon maximus*, of Cuvier, than any hitherto discovered, has been disinterred from a marl-pit, near Newburgh, Orange county, New York. The following account of this magnificent specimen of the ancient mammalia of our country, is derived from the "*American Quarterly Journal of Agriculture and Science*," of which Dr. Emmons, of Albany, and Dr. Prince, of Newburgh, are the conductors.

The skeleton was found by the workmen in the marl-pit, in August, 1846, and at the close of the second day they had succeeded in exhuming the entire skeleton, with the exception of the toes of one foot, which were probably carried out with the marl.

The marl-pit is of small dimensions, and consists of a bottom of deep mud, on which lies the marl, then moss, and peat at the surface. The bones lay under the moss and peat, and only about seven feet from the surface. The back of the skeleton was upwards, and the whole position was that of an animal which had perished in ineffectual struggles to extricate itself from the mire.

The most curious and interesting of this part of the narrative, is the finding, in the midst of the ribs, imbedded in the marl, and unmixed with shells or carbonate of lime, a mass of matter, composed principally of the twigs of trees,

broken into pieces of about two inches long, and varying in size from very small branches, to those of half an inch in diameter. There was mixed with these, a large quantity of finer vegetable substance, like finely divided leaves, the whole amounting to from four to six bushels. This was undoubtedly the contents of the stomach, the same material being found to the distance of three feet in the direction of the last intestine. This being the only instance in which such a discovery has been made, it proves at once the herbivorous character of the genus, and the comparatively recent period of its destruction.

Osteological Description. The skull.—The bones of the skull are of enormous size, and in a fine state of preservation. The width, 2 feet 9 inches. The orifice for the spinal marrow, 3½ inches in diameter. The frontal-bone, between the orbits of the eyes, is 2 feet 4 inches wide. The cavity of the brain is small, occupying only the lower part of the skull. Between the origin of the tusks is a cavity as large as that of the brain. Length of the head, 4 feet 1 inch; weight, with the tusks, 694 pounds.

The Tusks.—The insertion of the tusks into the intermaxillary bones, is 2 feet 5 inches, extending quite back to the orbits. Tusks, 10½ feet in length, and 2 feet 1 inch in circumference where they enter the socket. "With regard to the direction of the tusks," the authors say, "we are convinced from observation of a number of skulls, that their direction is as accidental as the horns of cattle. Some follow the first curve downwards and outwards, the points in one which we have seen being eleven feet asunder. In the skull of this skeleton, they first curve downward and outwards, till they are seven feet apart, when they are bent inwards and slightly upwards, till they approach at the points within two feet of each other. The socket of the tusks is curved and flattened, so that it was impossible for the tusks to have turned in them during the decay, as is supposed by many to have been the case."

In the end of the lower jaw, and on the left side of the commissure, or junction of the two bones, is a small round tooth, or rudimental tusk, eleven inches in length, and one inch and a half in diameter, inserted into a socket seven inches deep. On the other side is a partial socket, as if another tooth had been there. These rudimental tusks show that the animal was a male. (*See* 336.)

The Neck and Back.—The bones of the neck are seven; of the back, nineteen, and of the loins, three. The first seven bones of the back are characterized by very long spinous processes, the longest measuring two feet.

The Ribs.—These are forty in number, twenty on each side, the longest measuring 4 feet 7 inches.

The Scapula, (shoulder-blade.)—This is 2 feet 10 inches long, and 2 feet 9 inches wide, having a long sharp acromion process.

The Pelvis.—This large bone, to which the femur or thigh-bones are attached, measures 6 feet 1 inch across.

The Femur, (thigh-bone) is 3 feet 10 inches long, and 17 inches in circumference in the middle. Its head is 2 feet in circumference.

The following are the dimensions of the entire skeleton:

Length in a straight line, ...	20 feet.
Length by the curve, ... - . .	29 "
Height of the head, ...	12 "
Height of the back, ...	10 "
Width of the pelvis, ...	6 "
Length of the tusks, ...	10 "

Weight of the whole skeleton, 2,000 pounds; estimated weight of the animal, 20,000 pounds.

The above account shows this to be by far the most perfect, as well as the largest skeleton of the Elephant genus yet discovered. That it was the Mastodon *maximus*, or *giganteus* of Cuvier, which belongs to the Elephant family, the above description sufficiently proves. The rudimentary tusks in the lower jaw (336) appear to be characteristic of the American species, and by which it is distinguished from all the others determined by Cuvier.

332. *First account of the Mastodon.*—Dr. Ure states that the first notice of what afterwards proved to be the Mastodon, is contained in a letter from Dr. Mather, in America, to Dr. Woodward, of London, dated 1712, intimating that bones and teeth of enormous magnitude had been discovered at Albany, and which he supposed to be those of giants. In 1767, several chests of these remains were sent to Lord Shelburne, and examined by the celebrated Dr. William Hunter, who gave the first scientific description of them, published in the *Phil. Transactions*, for 1768.

Where is the Mastodon first mentioned? What species in this country?

333. *Great numbers found at Big-Bone lick.*—The most remarkable locality of these remains in this, or probably any other country, is at Big-Bone *lick*, in Kentucky. At this place the bones are found imbedded in dark-colored mud and gravel, which appears once to have been a bog or marsh. The water here is brackish, owing to the vicinity of salt-springs: and the great number of *big bones* are those of the animals which came to *lick* the salt, and perished in the mire of the vicinity. A traveler who visited this place more than eighty years ago, saw portions of the bones of more than thirty mammoths, as they were then called. Recently it has been estimated that the skeletons of more than 100 mastodons, and 20 elephants, have been carried from this vicinity, Very few of these, however, were entire, some wanting legs, some heads, &c.

334. *Size of the Mastodon.*—The great Mastodon appears to have been about the size of the Indian elephant; and in external appearance it probably did not differ materially from that animal. Its trunk, tusks, and feet, and the whole skeleton, appear to have been identical with those of the elephant, the chief difference being in the dental system, which, with respect to the grinders, has been above illustrated and described.

335. *Dental System of the Mastodon.*—Cuvier made some curious discoveries with respect to the teeth of this animal. The number of grinders in the adult, as before stated, was four in each jaw. Of these, the two front ones, in the upper jaw, have six points, and the other two in the same jaw have eight points, *Lign.* 67. In the lower jaw, the two anterior ones have also six points, and the posterior ones ten. But it appears that the great Mastodon had, *successively*, at least four grinders on each side of its two jaws; though, as in the elephant, these teeth never all appeared at the same time. Their *succession* took place, in both animals, from behind, forwards. When the posterior grinder began to cut the gum, the anterior one was greatly worn, and ready to drop out. In this way, they replaced each other. There does not appear to have been ever more than two on each side at the same time, in full exercise, and in old age, only one. Thus the effective

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What is said of the number of Mastodons at Big-Bone lick? Why is this place so called? What was the size of the Mastodon? What is said of the dental system of the Mastodon?

number of grinders in youth was eight, but in old age only four. The large ones weigh from 10 to 12 pounds each.

336. *In the British Museum*, there is a series of specimens, illustrating the dental system of the fossil elephant and the mastodon. From these it is proved that these two animals can hardly be regarded as distinct genera; for it is said the dental organs present every modification of structure, from the tubercular prominences on the grinder of the mastodon, to the waved ribands of enamel on those of the elephant. This collection, it is said, also demonstrates that all the bones and teeth, apparently, of several species, and, as some have supposed, of distinct genera, belong but to one grand Mastodon, the M. *giganteus* of Baron Cuvier; it also proves that the young mastodon had a pair of tusks placed horizontally in the lower jaw; and that but one of these was developed in the adult, and that only in the male. M. C. p. 831.

Thus did the young mastodon present the singular spectacle of *four* tusks: and it was from this circumstance that an American naturalist proposed a new genus, to be called *Tetracaulodon*, in allusion to its number of tusks.

337. Genus HIPPOPOTAMUS, (*river-horse.*)—There is only a single species of this animal existing. It is amphibious in its character, inhabiting the large rivers of Africa, and feeding on the vegetables along their shores. When full grown, it is exceedingly unwieldy and disgusting in appearance, being about 12 feet long, 5 or 6 feet high, and very thick set. The fossil species determined by Cuvier, are two, and perhaps three; all much smaller than the living, one being only about the size of a wild boar.

There is a peculiarity in the grinders of this animal, which appears to distinguish its dental system from all others. The lineaments of the crown are three-lobed, or trefoil-like, as shown by *Lign.* 68, being the form of the second grinder on the left side. This singularity will make the teeth of this genus readily known. This tooth is seven-ninths of the natural size, the roots being concealed by a portion of the jaw.

What is said to be proved about the several species of Mastodon? What is said of the four tusks of this animal? What peculiarity in the grinder of the Hippopotamus?

LIGN. 68

Hippopotamus' tooth.

The remains of this genus are not nearly so numerous as those of the elphant, though in Tuscany, considerable numbers have been found. They have also occurred in several parts of England, particularly in the Kirkdale cave. Perhaps the paucity of these bones may be accounted for, by the circumstance of the amphibious habits of this animal, and their inability to wander to any great distance from the shore, so that their remains might have been more exposed than those of the elephant to have been swept into the sea.

338. Genus RHINOCEROS, (*horned-nose.*)—There are three existing species of this genus. 1. That of India, with a single horn on the nose, and a rugous, plaited skin; the cutting-teeth being separated by a space from the grinders. 2. That of the Cape of Good Hope, with two horns, the skin smooth, without folds, and no cutting-teeth. 3. That of Sumatra, with two horns, the skin but slightly rugous, thus resembling that of the Cape, but having cutting-teeth like that of India.

On comparing the teeth of the existing species with those found in the fossil state, Cuvier determined that they were so different as to constitute another species of this animal, and whose remains are now to be found only in the fossil state.

The remains of the extinct rhinoceros were first discovered in sinking a well near Canterbury, in England, seven

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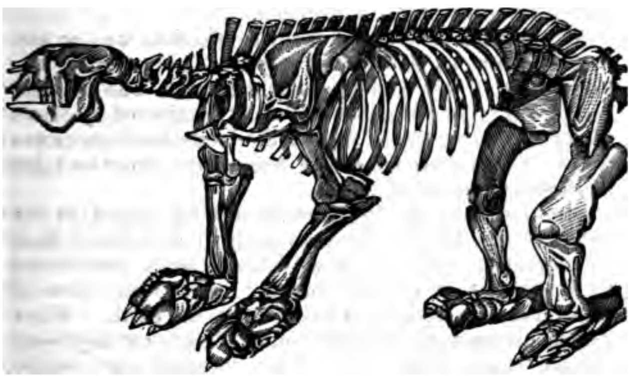
What is the meaning of Rhinoceros?

teen feet below the surface; since which, its bones have been found in various parts of England, Germany, and Prussia.

339. MEGATHERIUM, (*a huge wild beast.*)—This has heretofore been the most rare of all the great fossil quadrupeds. The first skeleton was sent from Buenos Ayres, in South America, to Madrid, in 1789, where it was set up in the Royal Cabinet, in the manner which has since been followed by Mr. Peale, of Philadelphia, with respect to the mastodon, and Prof. Adams, of St. Petersburg, in preparing the Siberian elephant, as already described.

A minute description of the Megatherium, was published soon after it was mounted, illustrated by five copperplate engravings. This appears to be the only entire skeleton yet discovered, and is represented by *Lign.* 69.

LIGN. 69.



Skeleton of the Megatherium.

Dr. Buckland, in the *Bridgewater Treatise*, has described this animal, in more than twenty pages, with numerous figures. In its osteology, it is allied to the Sloth, presenting an apparent monstrosity of form and structure, which have greatly perplexed the fossil osteologists who have attempted to describe the habits of the animal from its

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What is the meaning of Megatherium? Where first found? Is it a common fossil or not?

anatomical structure and proportions. It was supposed, like the Armadillo, to have been covered with a bony armor or shield, of an inch or two in thickness, fragments of which were found with the bones of the animal.

"A covering of such enormous weight," says Dr. Buckland, "would have been consistent with the general structure of the Megatherium: its columnar hind-legs and colossal tail were calculated to give it due support; and the strength of the loins and ribs, being very much greater than in the elephant, seems to have been necessary for carrying so ponderous a cuirass as that which we suppose to have covered the body." Bd. p. 127.

It seems, however, that this animal was not destined to carry such a burden: further inquiries, and the discovery of other remains to which it appears these bony coverings belonged, having shown that it was not the Megatherium, but a colossal animal, called, by Prof. Owen, Glyptodon, which wore the shield in question.

The remains show that the Megatherium was an animal of enormous size and strength. The length of the skeleton is 12 feet and the height 8 feet. The fore-feet are a yard in length and a foot wide, terminated by claws of corresponding size. Across the haunches it measures 5 feet, and its thigh-bones are about three times as large as those of the elephant.

340. *Habits of the Megatherium.*—With respect to the habits of this huge animal, its teeth showed that it lived on vegetables, while its claws indicate being constructed for digging; that it most probably lived on the roots of trees, and, if so, perhaps it burrowed in the earth. What a phenomenon to the imagination at the present day!—an animal, larger than an elephant, running along under ground, like a mole, leaving a path behind large enough for a horse and wagon to follow, and perhaps at the same time throwing up a ridge on the surface that would stop the career of a stage-coach! If he only burrowed like a rabbit, what a mountain of earth he must have thrown out!

The length of the neck proves that this animal had neither tusks nor proboscis, like the elephant and mastodon; since it could not have supported so heavy an apparatus at such a distance from the body.

What is said of the armor of the Megatherium? What of its habits?

341. Megalonyx, (*great-clawed.*)—So named from the size of its claws.

This is another of the lost animals of the former world. It belonged to the same genus as the megatherium; but Cuvier, on comparing their bones, found that they were of a different species, the latter being in all respects like the former, except that it was only one-third the size.

The bones of this animal were found in Green-Briar county, Virginia, much decayed, and only sufficient to form a small part of a skeleton.

342. Mylodon, (*molar-tooth.*)—This is the name by which Prof. Owen has distinguished an animal, the bones of which were found in the vicinity of Buenos Ayres. They were at first supposed to belong to a species of Megalonyx, but it appears, from its osteology and dental structure, to be more nearly allied to the megatherium. The skeleton is nearly entire, only a few bones being absent, these probably having escaped the search of the collector. It measures eleven feet from the skull to the extremity of the tail, the latter being three feet in length; the circumference of the trunk, around the tenth pair of ribs, is nine feet nine inches.

From certain peculiarities in the skeleton of the Mylodon, Prof. Owen assigns to this creature the task of uprooting and felling trees, and then feeding on the foliage of the forest it has laid prostrate. A remarkable development of the substance of the bones of the skull is presumed to have been a provision against the fatal effects of a fracture of the cranium, to which the Mylodon, from its uprooting propensities, is conjectured to have been peculiarly exposed; but it seems that this provision was not always a sufficient guard, since the skull of the animal bears proof of having been twice fractured, from both of which it recovered. "Whoever looks at the skeleton," says Dr. Mantell, "will perceive that the fore-feet are admirably adapted for seizing and wrenching off the branches, and the hind-feet for clasping the trunk of a large tree; and there is nothing to forbid the supposition that the animal might have obtained a constant and ready supply of food by climbing up the stem to a sufficient height, and wrenching off the branches." M. C. p. 874.

What is the meaning of Megalonyx, and where was it found? What does Mylodon mean, and what were the habits of this animal?

343. RODENTIA, (*gnawers.*)—Dr. Buckland found the fossil remains of several of this order in the Kirkdale cave, as the Rabbit, Mouse, and Water-rat. The bones of the Beaver and Porcupine have also been discovered.

344. MARSUPIALIA, (from *marsupium*, pouch, in which this tribe carry their young.)—The Opossum and Kangaroo are examples. The fossil remains of animals, allied to both of these species, have been found in France and England. At present the Kangaroo is exclusively a native of New Holland, and the Opossum of North America.

345. CARNIVORA, (*flesh-eaters.*)—The fossil bones and teeth of numerous species of this order have been discovered in fissures and caverns in various countries. In most cases, they have been found in the same caverns with the remains of many other animals, as will be seen from the account which follows.

BONE CAVERNS.

346. Dr. Buckland, long since, made the subject of osseous caverns highly interesting and instructive, by the publication of his great work, *Reliquiæ Diluvianæ*. Before the appearance of that work, little was known on the subject; nor did geologists consider the fossils found in such situations as legitimate objects of inquiry, being, as was supposed, of modern origin. It is true, that the remains of some animals, found in caves, had occasionally attracted notice; but no one appears to have inquired how, or by what means, they could have found their way to such places: nor was it until after the celebrated cavern of Kirkdale was discovered, and its contents described, that other caverns became the subjects of geological investigation.

After the description of that cave, notices of others, containing bones, have become so numerous, that we have not room even for a catalogue of their names and places; and there is no doubt but these will ultimately be the means of producing a body of geological evidence of much importance.

Caverns common in limestone formations.—It appears that most, if not all, extensive limestone formations contain caverns, some of which are of great extent, and have

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What are the Rodentia? What the Marsupialia? What the Carnivora?

long been admired for the brilliancy of their stalactites, and the pillar-like forms which they present. The island of Crete contains a great cavern, which has long been the wonder of travelers; and throughout the whole island, Tournefort says, there is *a world of caverns*.

347. KIRKDALE CAVERN.—This cavern, in which such quantities of organic remains were found, is situated in Yorkshire, England. It was first discovered by some workmen in 1821, its mouth being then nearly concealed by stones and earth. On removing these, and exploring the interior, there was found a cavern, 240 feet in length, 14 feet high, and from 7 to 3 feet wide. The rock being of limestone, its roof was covered with hanging *stalactites*, and its floor, in many places, incrusted with *stalagmites*.

(*Stalactites* are formed by the percolation of water through limestone rocks, by which calcareous particles are dissolved, and subsequently left by the evaporation of the water on the interior of the cavern; where the water, dripping down, and leaving these particles, they ultimately form stones, exactly in the shape of icicles, which are often increased to a large size by the deposition of stony particles in concentric circles.)

(*Stalagmites* are formed by the water which falls from the stalactites to the floor of the cavern, where by evaporation it deposits its calcareous matter. Sometimes the hanging stalactite and the rising stalagmite meet each other, and, joining, form pillars, which extend from the floor to the roof of the cavern.)

The floor of the Kirkdale cavern was covered with a coat of soft mud and loam, about a foot thick, and in this were found the bones of various animals. These were in a high state of preservation; and, though broken, none appeared as though they had been worn by the action of water or sand, which would probably have been the case had they been drifted there in the naked state.

The genera of animals to which the bones in this cavern belonged, amounted to 23 in number, viz: Hyena, Tiger, Bear, Wolf, Fox, Weasel, Ox, Elephant, Rhinoceros, Hippopotamus, Horse, Deer, (three species,) Hare, Rabbit, Water-rat, Mouse, Raven, Pigeon, Lark, Duck, and Partridge.

What is a Stalactite. and what a Stalagmite? How were they formed?

A great proportion of these animals belonged to species now supposed to be extinct, though the genera of them all are still existing.

348. *This cave, a den of Hyenas.*—On examination of all the circumstances, Dr. Buckland came to the conclusion that this cave was once a den of Hyenas, and that the multitude of bones thus discovered were carried into this place by these animals, and therefore that the hyena, an animal now inhabiting only the hottest climates, once lived in England.

These bones were, without exception, broken or gnawed, so that among the vast numbers the cave contained, there could hardly be found all the pieces of a single limb, much less an entire skeleton. The great number of hyenas which had died in this cave, or whose skulls had been carried there, was proved by the great number of canine teeth which it contained.

Dr. Buckland states that one collector obtained more than 300 of these teeth; and as each individual has only four of this kind, these must have belonged to at least 75 of these animals. But from the number of such teeth found, besides the 300, and other circumstances, it was judged that not less than 200 or 300 hyenas had either perished in this cave, or that these heads had by some means been carried into it. Hence, it was concluded that this cave had been, for a long series of years, a den of hyenas, and that these bones were carried there for their food.

349. *Immense power of the jaw of the Hyena.*—The immense power of the jaw, which these animals possess, enables them to break and masticate bones in a manner which no other animal can do. When they attack a dog, it is said they begin by biting off his leg at a "single snap." After a part of his work on this subject was written, Dr. Buckland had the satisfaction of seeing a Cape Hyena, in confinement, crush the thigh-bone of an ox, in a manner which convinced him that the bones in the cave had undergone a similar operation. The animal bit off all the upper part of the bone, which he swallowed in the shape of fragments, licking out the marrow from the cavity. The lower part, being exceedingly hard, he did not

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How many species of bones were found in the Kirkdale cavern? How is it supposed these bones came in that cave?

eat; and with it Dr. B. compared the fragments of similar bones found in the cave. His words are: "I preserved all the fragments, or gnawed parts of this bone, for the sake of comparison by the side of those I have from the antediluvian den in Yorkshire; there is absolutely no difference between them, except in point of age."

(Under "*Change of Climate*," will be found further proof that Hyenas once inhabited England; at present, we resume the subject of *Bone Caverns.*)

350. GAYLENREUTH CAVERN.—In Germany, there are many caverns in which bones have been found; but among these, that of Gaylenreuth has attracted most attention, on account of its great extent and beauty, as well as the number of fossils it contains. This cave is situated in Franconia, and in the same neighborhood with several others, all of which have been described by Prof. Goldfuss, of Bonn, in a treatise expressly devoted to this subject.

LIGN. 70.

Gaylenreuth Cavern.

The gateway, or entrance to this cavern, is seven and a half feet high, and faces towards the east; and of this wonderful place Dr. Buckland gives the following account. The adjoining Lignograph is a diminished copy of that drawn by him.

The first grotto turns to the right, and is upwards of eighty feet long; being divided into four parts by the unequal height of the vaulted roof. On the bottom of this part there is an orifice, only two feet high, which leads to the second grotto. This runs first to the south, for sixty feet, being forty feet wide and eighteen high; it then turns to the west, through a space of seventy-five feet, becoming gradually lower, until its height is only five feet. The passage to the third grotto is very incommodious, winding through several corridors, being thirty feet wide and only five or six high. The loam on this floor is literally stuffed full of teeth and jaw-bones. Near the entrance of it is a gulf, of fifteen or twenty feet wide, into which visitors descend by a ladder. After going down, they arrive at a vault, fifteen feet in diameter and thirty in height; and on the side on which they descend is another grotto, all over bestrewed with bones. By going a little further still, you arrive at a new grotto, forty feet long, and a new gulf, eighteen or twenty feet deep. Even after this descent, another cavern presents itself, forty feet high, quite covered with bones. Another passage now leads through several caves, arcades, or grottoes, to the last and largest room, which is eighty-three feet in width and twenty-four in height, more copiously furnished with bones than any of the others.

A rift in the third grotto disclosed, many years since, another cave, fifteen feet long, by four wide, where the greatest number of Hyenas' and Lions' bones were found. The aperture to this room was much too narrow for the entrance of these animals. A peculiar tunnel, which terminates this cave, afforded an incredible number of the skulls of the above-named animals, quite entire.

The excavation on the extreme right, and lowest parts of the figure, does not belong to the original cavern, but has been sunk for the purpose of finding bones. Several cavities have been dug in different directions from this well, for the same purpose, in one of which there is the figure of a man holding a torch.

351. *Species of animals to which these bones belonged.*—Vast quantities of the remains of animals have been collected from these caverns; and, from careful inspection, Cuvier determined that about three-fourths of them belonged to the Bear, and that next in number were those

of Hyenas, Foxes, Wolves, Gluttons, and Polecats. A few only of the Lion or Elephant tribes have been found in these caverns.

352. *How came these bones in the places where they were found?*—The first question one would ask, after reading the above account, would be, "how the bones of so many different animals found their way to such a place?" But it is obvious that the answer to this question must depend on conjecture alone. The following are Cuvier's conjectures: "It is scarcely possible," says he, "to imagine any other than the following general causes, that can have placed these bones in such quantities in these caverns. First, they are either the remains of animals, which dwelt and died peaceably in these chambers; or, Second, of animals which inundations and other violent causes carried in; or, Third, of animals which had been enveloped in stony strata, whose watery solution produced the caverns themselves, the soft parts of the animals being washed away by the agent which scooped out the mineral substance of the caves."

The last hypothesis is refuted by the circumstance, that the strata surrounding the caverns contain no bones; and the second, by the entire state of preservation of the smallest angles of these remains, which precludes the idea of their being rolled, or transported from a distance. We are therefore, says Cuvier, obliged to return from these to the first cause, whatever difficulties it may present. And these it must be apparent are not a few; for laying aside the great distances from the mouth of this series of caverns, at which some of the bones were found, and the total darkness of the whole, it seems that the greatest numbers occurred in places so narrow, that the animals in the living state could not have entered, in which cases, it is clear that they could not "have lived and died peaceably in the places where their bones are found." It is possible, however, that these caverns might have been diminished by stalactical incrustations.

353. *Dr. Buckland's conjectures.*—Dr. Buckland supposes that the contents of these caverns are due to two causes, viz: to the deaths of the prowling animals which inhabited them, and to the bones of other animals, which

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What was Cuvier's theory respecting these bones? Is this satisfactory?

these brought home for food, and this undoubtedly is the true theory. The elephants and other large animals which do not inhabit caverns, and whose bones are found in them, must obviously have been conveyed there in detached portions; and since the bones of hyenas are found with them, and it is known that these animals carried their prey to such secret places, it is an obvious conclusion that such were the means by which, in a long series of years, such quantities of osseous fragments were accumulated.

354. CAVERN OF KULLOCK.—The immense quantities of organic relics, which have been deposited in some of these caverns, may be best conceived of by the following statement of Dr. Buckland:

In the cavern of Kullock, the size and proportions of which are nearly equal to those of a large church, there are hundreds of cart-loads of black *animal-dust*, entirely covering the whole floor. The quantities of animal matter accumulated on this floor, is the most surprising, and the only thing of the kind I ever witnessed; and many hundreds, I may say thousands of individuals, must have contributed to make up this appalling mass of the dust of the earth. *Reliq. Diluv.* p. 138.

On the same cave Cuvier says: "I have stated that the total animal matter that lies within this cavern, cannot be computed at less than 5,000 cubic feet. Now, allowing two cubic feet of dust and bones for each individual animal, we shall have, in this single vault, the remains of at least 2,500 bears." We should think that one cubic foot of dust is as much as ought to be allowed to each bear, making the number 5,000 instead of 2,500.

OSSEOUS BRECCIA.

355. In Mineralogy, BRECCIA is a rock composed of angular fragments of other rocks, joined together by some kind of cement. In *osseous breccia*, the bones take the place of the fragments of stone.

Osseous or bone breccias, are found in many places on the coasts of the Mediterranean sea, as at Gibraltar, Cette, Nice, Corsica, &c. These compounds are found filling

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What is said of the number of animals in the cave of Kullock? What is osseous breccia?

the fissures of calcareous rocks; and it is a singular and curious circumstance, that in all these places, as well as in Dalmatia, Sicily, and Cerigo, though so distant from each other, these conglomerated fragments of bone are similar, and appear to have belonged to the same species of animals. They are the relics, chiefly, of ruminants, such as the deer, mixed with a few lions' and panthers' teeth, and sometimes the bones of rats, and occasionally of other animals. The pieces of bone are contained in a red earthy concretion, resembling highly burned bricks, but spongy or porous in texture, the cavities being of various sizes, and occasionally interspersed with sparry, calcareous incrustations. As the bones are not pressed together, it is reasonable to suppose, that the cement which contains them, must have been progressively deposited around them, as they fell into the fissures of the rocks where they are found. The bones in general appear to have been broken in pieces before receiving their cement, or calcareous incrustations. They are entirely separated from their organic arrangements, but exhibit no signs of having been rolled, or transported.

356. The stony fragments which this breccia sometimes embraces, are coarse-grained limestone, of a dark color, containing now and then veins of white spar, which appear to have been rolled, or water-worn. In size they vary from that of the fist to small grains.

These bones do not belong to any existing species of animals. In the bone rock of Gibraltar, Cuvier found those of a deer, and of a hare, both of unknown species. It is unnecessary to be more particular in the description of these curious deposits, as they occur at different localities, having already observed that they are all similar in appearance and composition.

The breccia of Dalmatia is the most extensive of any discovered, stretching along the whole coast of that country. Its structure and aspect are the same as that ot Gibraltar.

357. *Conjectural origin of bone breccia.*—With respect to the origin of these bone rocks, Dr. Buckland supposes that the bones of the extinct species of animals, are those which fell into the fissures of the rocks before the deluge

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What is meant by bone breccia? What is the appearance cf this compound? Do the bones belong to existing species, or not?

and there perished. The same author has shown that the red cement, in which these remains are inclosed, is an earthy loam, differing merely in color from that which fills the caves and fissures of rocks in Germany, and constitutes the diluvial loam on their bottoms.

It may be observed that these breccias are peculiar to limestone rocks. Now, lime is known to be soluble in water, in small quantities, and hence the calcareous spar, with which these bones are often surrounded and impregnated, is readily accounted for. The soil or cement, including the bones, is also hardened by the infiltration of the same substance.

358. Osseous Breccia of Australia.—This has been more recently discovered. From a communication of Major Mitchell, to the London Geological Society, it appears that this breccia bears a great resemblance to that of Europe. The principal cavity where it occurs is an irregular kind of well, or natural fissure, accessible only by ladders and ropes, and the breccia is a mixture of limestone fragments of various sizes, and bones enveloped in an earthy red calcareous stone. But this differs from the Mediterranean cavity in this important particular, that the bones it contains, instead of being chiefly those of the deer, are those of marsupial animals, peculiar to that country, the Kangaroo and Wombat, and which are still living. The bones of the Elephant, and also of some species of other animals not known to exist, are occasionally found with the others, but the principal parts are composed of living species. This breccia was therefore probably formed at a later period than that of the Mediterranean.

What is conjectured to have been the origin of bone breccia?

PART III.

CHAPTER XXVI.

ROCKS,

THEIR CLASSIFICATION AND DESCRIPTION.

359. THE four great Classes of Rocks are the following: The AQUEOUS, the VOLCANIC, the PLUTONIC, and the METAMORPHIC. This is Mr. Lyell's division, and is adopted on account of its simplicity and truth. The former division of rocks, in which *granite*, *gneiss*, and *mica-slate*, were considered to have been first formed, and therefore were called *Primitive* or *Primary*, has been shown, by geological observations, not to be founded on facts; since granite, in many instances, has been observed to overlay, or rest upon other rocks, which had been supposed secondary. The classification has therefore been changed, in order to meet the phenomena presented by the rocks themselves.

The grand Classes are sub-divided, according to their nature or appearances, or sometimes according to priority of age, as will be seen as we proceed.

I. AQUEOUS ROCKS.

360. The aqueous rocks, sometimes called sedamentary, or *fossiliferous*, because they contain fossils, cover a larger part of the earth's surface than any of the others. These rocks are deposited from water, and hence they are *stratified*, or divided into distinct layers, or strata. It is easy to conceive how these strata are formed, for whenever a running stream, charged with mud, or sand, has its velocity checked, (as when it enters a lake, or the sea, or overflows a plain,) the sediment, previously held in suspension, and which it had acquired by its motion, sinks by its

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What are the four great classes of rocks? Why has the name primitive been changed? How are aqueous rocks formed?

own gravity to the bottom, and thus a stratum is formed. If this process is repeated in the same place, another layer is formed over or upon this, and so on indefinitely. If these strata are carefully examined, it will be found that, although they consist of the same materials, the grains forming the under sides are always coarsest: which arises from the circumstance, that the largest particles of the sediment first sink to the bottom.

361. *Formation.*—This geological term is applied to any accumulation of stony matter in sufficient quantity to form strata or rocks, having characters peculiar to themselves. Thus we say, stratified, marine, fresh-water, crystalline, volcanic, ancient or modern *formations*; the name depending on the source, structure, or time of the accumulation.

In the examination of rocks, if they consist of layers or strata, we must conclude at once, that, whether ancient or modern, they must have been formed by the deposition of that solid matter from water: for we can conceive of no other means by which strata could have been formed. In all cases, we may also infer, that each stratum, though found with hundreds of others resting upon it, was once at the surface, or above all the others on which it rests. When, therefore we find shells, or other remains, or pebbles, in deep strata, perhaps hundreds of feet below the surface, it is quite easy to solve the (to some a) mystery, by remembering that the stratum on which they rest, was originally the highest, that is, above all below it, when the relic, sinking to the bottom of the water, was afterwards covered by other depositions, each forming a layer, and each in its turn being above all the others.

362. *Fossils in strata.*—Fossils, as already explained, are any organic bodies, whether belonging to animals or plants, which have been buried in the earth by natural causes.

Now, the remains of animals, especially shells, have been found buried in strata, hundreds of feet from the surface, in almost every part of the earth. These shells, being the remains of aquatic animals, afford still stronger evidence that the strata in which they are found were formed under water. Some being marine, show that the rocks in which they occur, were formed under the sea;

What is meant by formation? Explain how shells came to be in strata far below the present surface? What is a fossil?

while others, being fresh-water shells, as clearly evince that their strata were made at the bottoms of lakes.

Now, such formations, containing shells of both the kinds above named, are found, not only far distant from the sea, or lakes, but thousands of feet above the present levels of either, and also far below them; and even to the utmost depths to which the earth has been penetrated. In the strata of the Alps, fossil sea-shells are found to the height of 8,000 feet above the level of the sea; in the Andes, more than 13,000, and in Himalaya, more than 15,000 feet above the same level. We must conclude therefore, since it is certain that these strata were formed under water, and that the shells they contain could only have lived in the sea, or in lakes, that the rocks now containing them, being the same in which they were originally imbedded, must have been raised from the bottom of the ocean, or from lakes, to their present elevation, or sunk below their original level down to the places where they now occur. We shall see hereafter that these great changes in the primitive levels of the earth are due to the tremendous power of volcanic causes.

II. VOLCANIC ROCKS.

363. These rocks owe their origin, not to water, but volcanic fire, that is, fire in the depths of the earth. They appear to be of all ages, from the most ancient to the most recent, and in volcanic districts, are occasionally forming at the present day. They are entirely devoid of fossils, nor do they show any signs of stratification. Most of them are more or less porous in their structure, and some kinds contain crystals, or fragments of other minerals. They are often observed to rest upon stratified rocks of the more recent formation, falling into their cavities and fissures, when in a melted state. These rocks, though quite extensive in some countries, form a much less portion of the earth's crust than the aqueous rocks.

III. PLUTONIC ROCKS.

364. These include what were formerly called Primitive unstratified rocks, especially the Granites and Por-

At what heights and on what mountains have sea-shells been found? By what means is it supposed they occupy such situations? What are the volcanic rocks?

phyry. Like the volcanic rocks, they are supposed to owe their origin to heat, though under different circumstances. Instead of being compact in structure, they are composed of crystals of various sizes. The composition of Granite, is *quartz*, *feldspar*, and *mica*, all in distinct crystals, differing in size, from mere grains to several inches, or even a foot in diameter. This rock is of various colors, depending on those of the materials of which it is formed. The quartz is most commonly white, but sometimes reddish or brown; the feldspar is also white, passing into flesh-colored, and occasionally brownish. The mica is black, green, or white. These colors being intermixed, the prevailing colors of granite is gray, often reddish from the color of the feldspar; brown, when penetrated by oxyd of iron, and less frequently, nearly black, when the mica is in more than common proportion.

They are called crystaline rocks. They never contain organic remains, nor are they stratified like those which are deposited from water.

These rocks differ from the volcanic, not only in having the crystaline structure, but also in not having pores or cavities, which the entangled air gives to most volcanic products. Hence, while the volcanic rocks are known to have been formed near the surface, it is inferred, from these differences, that the granites were melted at great depths under the earth, or sea, and have cooled and crystalized under enormous pressure, where the contained gasses could not expand. From the hypothesis that these rocks were thus formed in the bowels of the earth, they have been named "Plutonic rocks," thus distinguishing them from the volcanic. The granites now form some of the highest mountains on the earth, and hence, the hypothesis, that they have been elevated by volcanic force to their present situations.

IV. METAMORPHIC ROCKS.

365. This class consists of the stratified rocks formerly called Primary, as *mica-slate*, *gneiss*, *clay-slate*, and some kinds of limestone, or marble. Their origin is more doubt-

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What are the plutonic rocks? To what do they owe their origin? What is the composition of granite? What its color? How does granite differ from volcanic products? How is it supposed this rock was formed? How elevated to its present height? What are the metamorphic rocks?

ful than that of the other classes. They contain no pebbles, or angular pieces of imbedded minerals, nor any traces of organic remains. Their stratified structure gives rise to the hypothesis, that they were originally deposited from water, like the first class, and subsequently changed by subterranean heat, so as to assume their present texture and crystaline appearance. In consequence of this supposed change, Mr. Lyell has given this class the name of *Metamorphic*, from the Greek *meta*, and *morphe*, signifying *transformed.*

Mr. Lyell has also suggested a new name for the Plutonic and Metamorphic rocks, as one great family, having exclusively the crystaline structure, and a common origin. His language is: "As all the crystaline rocks may, in some respects, be viewed as belonging to the same family, whether stratified or unstratified, it will be convenient to speak of them by one common name. But the use of the term *primary* would imply a manifest contradiction, for reasons which the student will now comprehend, (367.) It is indispensable, therefore, to find a new name, one which must not be of chronological import, and must express, on the one hand, some peculiarity, equally attributable to granite and gneiss, (to the plutonic as well as the *altered* rocks,) and on the other, must have reference to characters in which the rocks differ, both from the volcanic and from the *unaltered* sedimentary strata. I have proposed, in the *Principles of Geology*, the term 'Hypogene,' for this purpose, derived from two Greek words, meaning *under* and *to be born*, being in reference to the theory, that these rocks were formed in the bowels of the earth, and not at the surface."

The relative positions of the Hypogene rocks, as they often occur, are represented by *Lign.* 71. The centre or middle mass 1, projecting high above the side strata, is *granite*. The flanking planes 2, 2, are *gneiss*, appearing as though they had been elevated to their present situation by the tremendous force which lifted up the granite. The *mica-slate* 3, 3, is seen resting against the gneiss. The two latter rocks have the appearance of once having been in a horizontal position, the mica-slate being superincumbent on the gneiss, and this on the granite, and we

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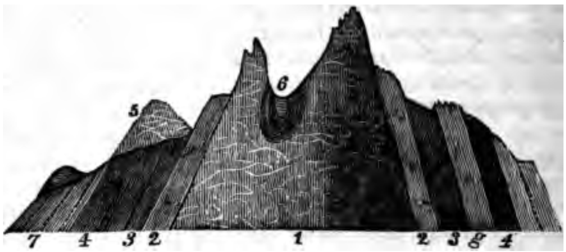
What is meant by metamorphic? What is the meaning of hypogene, and why is the name applied to the crystaline rocks?

shall see, in another place, that this was undoubtedly the case. The letter *g* shows a bed of *quartz*, included in the micaceous beds, and, being much less subject to disintegration by the weather, rises above the mica. The beds 4. 4, are clay-slate, or roof-slate, on the outside of the mica-slate. The overlaying mass is *porphyry*, resting on the mica and clay-slate. A small bed of mica-slate, 6, shows the strata bent, forming a dish-like cavity between the central peaks of the granite. Above 7, is seen a bed of *clay* and *gravel*, in strata, showing their more recent formation, as they rest on the nearly horizontal strata of the mica-slate.

LIGN. 71.



Hypogene rocks.

In many instances, there is sufficient proof exhibited by the rocks themselves, that metamorphic strata were once in a horizontal position, and that they owe their present nearly vertical posture to a force exerted from below, and by which the granite, being elevated, has raised up the once superincumbent strata, and given them their various inclinations. (*See Elevation of Continents.*)

Explain Lign. 71.

CHAPTER XXVII.

AQUEOUS ROCKS;

THEIR COMPOSITION, NAMES, AND FORMS OF STRATIFICATION.

ARENACEOUS, OR SANDSTONE ROCK.

366. THIS rock is an aggregation of small particles of sand, which often cohere together without any visible cement, but are more commonly bound into masses by clay, silex, lime, or oxyd of iron. In nature, there will be found every gradation, from loose sand to the hardest sandstone rock. In the variety called *micaceous* sandstone, the mica is abundant, and gives this formation the appearance of a stratified rock. When sandstone is coarse-grained it is usually called *grit*. If the grains are rounded, and of the size of pebbles, it becomes a *conglomerate*, or pudding-stone, which consists of fragments of many kinds of rock, of different colors, bound together by the sand, with some kind of cement.

Sandstones vary in color, often according to that of the cement, by which its particles cohere. When this is oxyd of iron, it has a reddish color. They also differ in age, being called the *Old*, and *New*, Red Sandstone.

CALCAREOUS, OR LIMESTONE ROCKS

367. These rocks are composed of lime and carbonic acid; and hence are *carbonates of lime*. Chalk and marble are common examples. The varieties of this rock are numerous, sometimes consisting almost entirely of shells of various kinds, closely cemented together by calcareous matter, when it is called *shell*-limestone.

368. OOLITE.—This is a calcareous rock, consisting of globules, sometimes so small as to resemble the roe of fishes, and hence is called *Roestone*. It has generally a brown or ocherous color, and is a variety of common limestone, from which it does not differ in composition. These globules do not, however, in all cases, compose the entire mass; the oolite often running into common limestone.

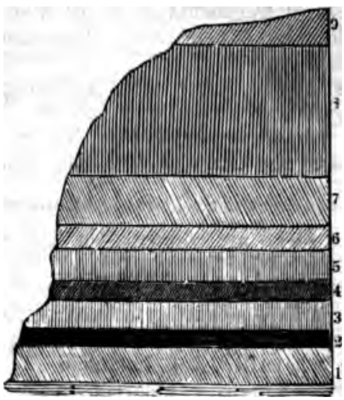
Of what are sandstones composed? What is micaceous sandstone? What is pudding-stone? What is grit? What is the composition of calcareous rocks? What are examples? What is Oolite? How is it formed?

In England, this formation is rich in organic remains; the bones of some of the largest fossil animals, and many of the best-preserved shells being found in it. It is often used as a building-stone, St. Paul's church and Somerset-house being constructed of it.

With respect to the manner in which these globules are formed, it is supposed that they originated in streams of running water charged with lime, by the gradual deposition of calcareous particles on a small nucleus, as a grain of sand, kept for a while in agitation by the stream.

369. Lias.—The name is said to be a corruption of *layers*, because this rock is usually stratified. It is one of the Oolite group, and often passes insensibly into that rock. It is an argillaceous limestone, and is usually found in conformable positions. It contains abundance of organic remains, and in England is particularly rich in those of the Saurian reptiles.

LIGN. 72.



Calcareous strata in Ohio.

370. *Dr. Hildreth, on the Oolite of Ohio.*—In this country, Oolite is common in some limestone districts. That which occurs on the Little Muskingum, in Ohio, is described by Dr. Hildreth, as follows: color yellowish white, when exposed to the air, but grayish white when taken from the bed; structure compact, fracture conchoid-

What kind of rock is lias? Why is it so called?

al, with an earthy surface; adheres to the tongue; composition, carbonate of lime, with a little carbonate of iron. In properties and appearance, it approaches nearly to chalk. It stands the weather without exfoliation, and would make a fine building-stone.

The associations of this rock in Ohio will be seen by *Lign.* 72. Order of the ascending series.

1. *Limestone*, compact, dark, and in strata, from 6 inches to 2 feet in thickness. The bed is 8 feet thick.
2. *Bituminous coal*, very pure, structure slaty, 2 feet.
3. *Water lime*, in thin beds, resting on coal, 6 feet.
4. *Chloritic rock*, color almost verdigris green, 4 feet.
5. *Lias*, stratified, and oolite, 8 feet.
6. *Calcareous tufa*, porous, as if pierced by worms, 6 feet.
7. *Sparry limestone*, brownish dove color, 30 feet.
8. *Sandstone*, with fossils in the lower strata, 100 feet.
9. *Argillaceous*, soil covered with timber, 10 feet.

371. CLAY-SLATE.—This is a rock of considerable extent in some countries. It is composed of *argil*, with silex and alumine, and hence is called *argillaceous* rock. It is stratified, and often shows *ripple-marks*, being thrown into gentle inequalities by the action of small waves during its formation. It often includes stones of small size, and not unfrequently runs into conglomerate or pudding-stone, on the one hand, and into sandstone on the other. The color of this rock varies from dark red, or brown, to that of slate. *Shale* is a variety of this rock, but is harder, perhaps from greater pressure, and is of a dark color; often contains bitumen, when it is called *bituminous* shale. When clay-slate is moistened by the breath, it always emits that peculiar smell called the argillaceous odor.

372. SILICIOUS LIMESTONE.—This is carbonate of lime, mixed with particles of silex, and is harder in proportion to the flinty matter it contains. Sometimes this rock is nearly pure lime, while other specimens are mostly formed of silex. The colors vary, as in common limestone, and it is often difficult to decide by the eye alone, whether a rock contains lime or not. In this case, a simple and sure method is the test by an acid. If diluted sulphuric acid

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What kind of rock is clay-slate? What is the color? What is shale? What is silicious limestone? How may the presence of carbonate of lime be certainly known?

be dropped on the specimen, and effervescence ensues, that is, if little bubbles of gas escape, it is certain that carbonate of lime is present; and when there is any doubt about the nature of the rock, whether it is calcareous or not, this will always give a sure decision.

The three rocks, last described, the *Arenaceous*, the *Calcareous*, and the *Argillaceous*, when they occur in the same district, frequently pass into each other, so that it is often difficult to decide to which species a specimen belongs.

CHALK.

373. In Great Britain this is a very important formation. It is also found in France, Germany, Italy, and Poland; but it is said, that no deposits of Chalk have been found beyond the limits of Europe. In the New World, through the whole extent of the two Americas, not a specimen has been found.

Mr. Lyell says that white chalk extends from the north of Ireland to the Crimea, a distance of more than 1,100 geographical miles; and in an opposite direction, from the south of Sweden to the south of Bordeaux, a distance of 840 geographical miles.

374. *Origin of Chalk.*—Although chalk, at the present day, is found at considerable distances from the sea, and far elevated above its level, still, it is considered of marine origin. This is inferred from the sea-shells which it often contains. Some of these, as the Terebratulæ, are known to have lived only in deep waters. Shells of the Nautilus, and the Belemnite, or internal bone of the Cuttle-fish, are also found in chalk. All these being marine animals, and their remains being abundant in chalk formations, their presence is considered ample evidence of its marine origin. Sponges, Sea-urchins, and Corals, are also common in this formation. Chalk is but very obscurely stratified, though in some instances there are signs of layers. The Infusorial origin, of at least a portion of this mineral, has already been suggested; the animalcules that formed it must therefore have been of the marine species.

375. *Origin of Flint in Chalk.*—The common nodules, of which gun-flints were formerly made, are exclusively

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What is said of the geographical extent of chalk? What is considered the origin of chalk?

found imbedded in chalk. Layers of flint, of various thickness, are also found in chalk beds, perfectly distinct from the chalk. The particles of silex, being of greater specific gravity than those of the chalk, probably fell to the bottom first, thus forming strata of their own. But supposing that the chalk contained a portion of silex in a free state, while the whole was mixed with water, and in the process of forming, it is difficult to imagine by what power these particles separated themselves from the surrounding mass, so as to form nodules so perfectly distinct from the matter which surrounded them.

GYPSUM.

376. This is a sulphate of lime, and is well known under the name of *Plaster of Paris.* It is usually a soft, white, or yellowish rock, with a texture resembling that of loaf-sugar. Sometimes it is beautifully crystalized in broad transparent plates, much resembling white mica in appearance. But the two may readily be distinguished by the elasticity of the mica, while the *selenite*, as this variety is called, is inelastic, showing no disposition to recover itself when bent. The selenite also turns white by the loss of its water of crystalization, when heated, while even a red heat does not change the transparency of the mica.

Gypsum is insoluble in acids, and hence does not effervesce, when tested in the manner above directed for carbonate of lime; and this circumstance will distinguish specimens of these two kinds of rock, which often nearly resemble each other in appearance.

Gypsum, like rock-salt, is never found in extensive formations. It is an aqueous rock, and from the organic remains found in it, is considered of fresh-water origin. Beds of this mineral commonly alternate with those of marl and limestone.

The greatest deposit of Gypsum described, is that in the vicinity of Paris, which extends about 60 miles. At Montmatre, near that city, two formations of this kind exist; the lower is composed of alternate beds, of little

What is said of the origin of flint in chalk? What is the composition of gypsum? In what form does it occur? How is gypsum known from carbonate of lime. Where is the deposit of gypsum, from which Cuvier drew so many extinct species?

thickness, consisting of gypsum, often crystalized, with lime and clay-marls. The upper formation is most important and remarkable. It is about 65 feet thick, and in some places lies immediately under vegetable mold. This is particularly interesting from the number and variety of organic remains found in it, and from being the source whence the celebrated Cuvier drew the skeletons of so great a variety of extinct species of animals.

377. Marl-slate.—Marl is a mixture of carbonate of lime and clay, generally containing abundance of small fresh-water shells. It is soft and loose in its structure; sometimes deposited in strata; but more frequently is found without any signs of aqueous deposition. It is of fresh-water origin, and of recent date. Some of the marl-pits of Scotland have afforded many organic remains of animals, but all of known species. On some soils, marl is an excellent manure, and is extensively employed for this purpose.

FORMS OF STRATIFICATION.

378. A series of strata sometimes consists of one of the above rocks, and sometimes of two or more in alternating beds. Thus, in the coal districts of England, for example, we often pass through several beds of sandstone, and below these, layers of shale and sandstone, or beds of shale, divisible into leaf-like laminæ, and containing beautiful impressions of plants. Then again we meet with beds of pure and impure coal, alternating with shale, and underneath the whole, perhaps, are calcareous strata, or beds of limestone, filled with corals and marine shells, each bed distinguishable from the other by certain fossils, or by the abundance of particular species of shells, or zoophytes.

HORIZONTAL STRATA.

379. The above description will convey an idea of the common phenomena of stratification. Each layer, whether of the same or of another rock, is a *stratum;* the whole are called *strata*, the process of forming is *stratification*, and the rocks so formed are *stratified.*

Whatever may be the direction of strata at the present

What is marl? What is a stratum? What are strata, and what stratification? In what direction are all strata formed?

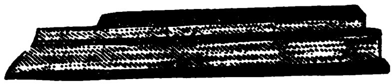
time, it is certain that their position was originally horizontal, or at least nearly so. "The reason of this arrangement," says Mr. Lyell, "can by no means be attributed to an original evenness or horizontality in the bed of the sea; for it is ascertained that in those places where no matter is deposited, the bottom of the ocean is often as uneven as that of the dry land, having, in like manner, its hills, valleys, and ravines. Yet, if the sea should sink, or the water be removed near the mouth of a large river, where a delta has been forming, we should see extensive plains of mud and sand laid dry, which, to the eye, would appear perfectly level, though, in reality, they would slope gently from the land towards the sea. This tendency in newly-formed strata to assume a horizontal position, arises principally from the motion of the water, which forces along particles of sand and mud at the bottom, and causes them to settle in hollows or depressions, where they are less exposed to the force of the current than when they are resting on elevated points. The velocity of the current, and the motion of the wave, diminish from the surface downwards, and is least in those depressions where the water is deepest." *Elements*, p. 80.

This subject may be easily illustrated, and by a very simple experiment. If an iron dish be set in the bottom of a running-stream, and nearly on a level with its surface, and then the mud and sand be stirred above it, the sediment will soon fill the dish to the brim; and if the experiment be repeated, the dish will be buried, and the bottom of the brook as smooth over it as though the dish had not been placed there. If the process be watched, it will be seen that the sediment falling into the dish remains there, being below the influence of the current, and that this will continue until it is full; when the bottom of the stream becomes level as before. A number of half egg-shells, with a little stone in each, to keep them in position, will show the same result, if used instead of the iron dish.

380. A series of horizontal strata is represented by *Lign.* 73. In these the stratification coincides with the line of the horizon. It is, however, very rare that such strata are observed, except in the most recent formations;

How is this illustrated by an iron dish?

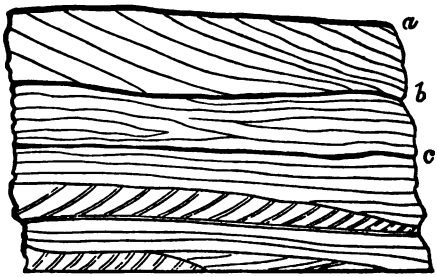
LIGN. 73.



Horizontal strata.

the secondary and tertiary strata, in nearly every instance, being more or less inclined. This, we shall show hereafter, is in consequence of disturbance after their formation, from volcanic forces, acting from below.

LIGN. 74.



False stratification.

381. False Stratification.—There is a phenomenon of frequent occurrence, in which may be seen a series of large or thick strata, each of which is composed of a number of smaller layers, placed obliquely to the general planes of stratification. To this diagonal arrangement, the name of "false stratification" has been given. Thus, in the annexed *Lign.* 74, we have several large beds of loose sand, yellow and brown, the lines *a*, *b*, *c*, showing the principal planes of stratification, which are horizontal. But the greater part of the subordinate strata do not conform to these planes, but have inclinations, more or less steep, from one to the other, these being sometimes in opposite directions. When the sand is loose and incoherent, as in the present case, the deviation from parallelism of the slant-

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What are horizontal strata? In what deposits are these strata found? What is meant by false stratification?

ing strata cannot possibly be accounted for, by any new arrangement of the particles during the consolidation of the rock. We must, therefore, suppose that at the bottom of the sea, as well as in the beds of rivers, the motion of the waves, currents, and eddies, often cause mud, sand, and gravel, to be thrown into heaps, on particular spots, instead of being spread uniformly, as is most commonly the case. Afterwards, perhaps, by a new current, the depressions between these little hills or mounds, being filled in the manner already described, the principal strata are again deposited, on which the current, by the overflow of the river, again produces an inequality of surface; after which, the same process is repeated. The appearance of these strata suggests this theory of the manner of their formations, as the only one which can account for such phenomena; and as we know nothing of the currents and counter-currents of deep water, except by the effects they have left on the bottom, perhaps this is as satisfactory an explanation as can be proposed.

LIGN. 75.

Ripple-marks.

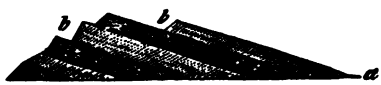
382. Ripple-marks.—The ripple-marks, so common on the surfaces of clay-slates and sandstones of all ages, a specimen of which is represented by *Lign.* 75, and which are so often seen in the sand of the sea-shore at low tide, seem to originate in the drifting of the sand along the bot-

What are ripple-marks? How are ripple-marks made?

tom, by the unequal action of the waves. These marks are only seen on shores where the water rises and falls in the form of waves, and their sizes appear to depend, more or less, on the amount of this elevation and depression. On shores which are swept by a broad ocean, they are on a larger scale than on the borders of bays or ponds, where the waves only rise to the height of a few inches. On this account, a great difference may be observed in their sizes on the same shore at different times. After a storm, during which the waves have risen to an unusual height, the impressions left on the sand, after the subsidence of the water, are wider apart, and the inequalities much greater, than will be seen at ordinary times.

Sometimes there may be seen two series of ripple-marks, crossing each other at various angles. This is caused by a change in the course of the wind, and consequently of the new direction in which the waves are thrown on the shore.

LIGN. 76.



Dip of strata.

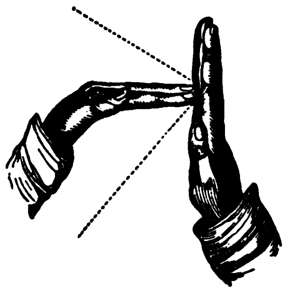
383. DIP.—The inclination of strata, from a horizontal position, is called their *dip*, the amount of the dip being the quantity of the angle which the line of inclination makes with that of the horizon. Strata forming a dip, are represented by *Lign.* 76. If the angle made by the meeting of the lines of the strata, *b b*, and the horizontal line *a*, be equal to 45° towards the east, then the strata are said to have a dip of 45° in that direction.

384. OUTCROP.—When strata protrude above the surface of the earth, or are uncovered, as on the side of a hill, so as to be seen, they are said by the miners to *crop out.* The uncovered ends of the strata commonly rise above each other, like stairs, or, as Mr. Bakewell has it, like a number of slices of bread and butter, laid on the side of a plate. In *Lign.* 76, the outcrop of strata is represented at

Is there any relation between the size of these marks and the waves? What is meant by dip? What is outcrop?

b b. Outcrop is a matter of much importance to geologists and practical miners, since the under, as well as the upper strata, can be observed at these points; and thus, without excavations or borings, not only the dip can be ascertained, but also the different kinds of rock with which a section of country is underlaid.

LIGN. 77.

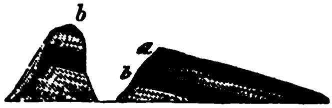


Taking angles.

385. *Simple method of finding the angles of inclination.*—Mr. Lyell employs the following method of ascertaining the amount of dip in stratified rocks: "It is rarely important," says he, "to determine the angle of inclination with such minuteness, as to require the aid of instruments. We may measure, within a few degrees, the angle, by standing exactly opposite to the cliff, where the true dip is exhibited, holding the hands immediately before the eyes, and placing the finger of one in the perpendicular, and the other in a horizontal position, as shown by *Lign.* 77. It is thus easy to discover whether the lines of the inclined beds bisect the angle of 90°, formed by the meeting of the hands, so as to give an angle of 45°, or whether it would divide the space into two equal portions. The upper dotted line may express a stratum dipping to the north; but should the beds dip precisely to the opposite point of the compass, as in the lower dotted line, it will be seen that the amount of inclination may still be measured by the hands with equal facility." p. 71.

What is Mr. Lyell's method of measuring angles of strata?

LIGN. 78



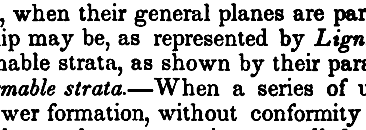
Outlier.

386. OUTLIER.—Strata are said to form *outliers*, when they constitute a portion of rock, or country, detached from the general mass of the same bed of which they evidently once formed a part. Thus, the bed *b*, *Lign.* 78, on the top of the hill, is an outlier of the principal formation *a b;* the intervening valley being scooped out, either by the general deluge, or some other means. The kind and thickness of the intercepted strata, as well as the range, are sufficient to prove that they were once continuous.

Escarpment.—Strata are said to terminate in an escarpment, when they end abruptly, as at *a b*, *Lign.* 78.

Mural precipice.—Mural signifies *wall-like*, and rocks are said to form such precipices, when they present naked and nearly perpendicular faces.

LIGN. 79.



Conformable position.

387. CONFORMABLE POSITION.—Strata are said to be *conformable*, when their general planes are parallel, whatever their dip may be, as represented by *Lign.* 79, *a a* being conformable strata, as shown by their parallel planes.

Unconformable strata.—When a series of upper strata rest on a lower formation, without conformity to the position of the latter, the upper series are called *unconformable*, as shown by *b b*, *Lign.* 79.

388. FAULT.—This is such a dislocation of the strata, that not only their continuity is destroyed, but the series

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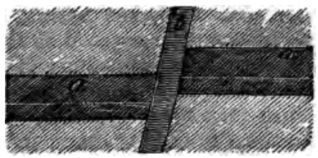
What is an outlier? What is an escarpment? What is a mural precipice? What are unconformable strata? What is a fault?

of beds on one or both sides of the fracture, are forced out of their original positions, so that it often happens in mining for coal, the workmen suddenly come to the apparent termination of the vein, by a wall of rock.

389. Dike.—This is a wall of rock interposed between the two sides or ends of a dislocation, and in consequence of which, the continuity of the beds is interrupted. If we suppose that the dike was once fused matter, as is the case with volcanic dikes, and forced up from beneath, and that on one of its sides the strata were elevated, or thrown down on the other by a convulsion, it would account for the phenomena of both dikes and faults; the first consisting in the dislocation of the strata, and the other, the wall by which they are intercepted.

LIGN. 80.



Fault and Dike.

This will be understood by *Lign.* 80, where *a a* represents the fault, and *b* the dike. The coal stratum, *a*, terminates at the dike on both sides; but on one side it is elevated, and on the other depressed. When, therefore, the miners, coming to the dike, and knowing that the bed of coal is either above or below their own level, they begin by searching on the other side. But here, at first, they find only sandstone or clay, the coal-vein being entirely lost, and their business as miners suspended. In attempting to regain the vein, the first question to be determined is, whether it has been thrown up, or cast down on the other side of the dike; and this, in general, is readily decided by the position of the dike, or its inclination, with respect to the fault. For experience has shown that, if the dike makes an acute angle with the upper surface of the coal-vein, the strata are elevated on that side; while, if the

What is a dike? What is the difference between a fault and a dike? On which side of the dike would you look for the lost coal-vein?

angle is obtuse, they are thrown down, as shown in the figure.

390. *Springs caused by dikes.*—Dikes being generally impervious to water, they obstruct its passage along the porous strata, and occasion it to rise towards the surface; hence, it frequently happens that numerous springs make their appearance along the course of a dike which is entirely under ground, the springs alone indicating its existence.

In some coal-fields, the strata are raised, or depressed, to the amount of four or five hundred feet; that is, there is this difference between the two strata in a perpendicular direction. Probably, in some instances, the strata have been moved on both sides of the dike, on one side raised, and on the other depressed, from the original level of the stratum.

Composition of Dikes.—Dikes which intercept coal strata, are most frequently composed of that kind of volcanic rock called *basalt*, but sometimes of indurated clay. They are, in thickness, from a few inches, to 50 or 60 feet, and sometimes even several hundred feet. Dikes are seldom noticed, except in mining districts, where they excite much interest in consequence of the disturbance they occasion to coal-veins; the workmen being sometimes thrown out of their regular employment for weeks, in regaining the vein which has thus been lost.

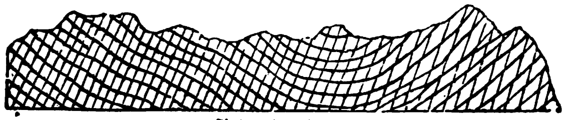
STRUCTURE OF SLATE.

391. Prof. Sedgwick has made some curious and important remarks and observations, on the difference between the planes of stratification and those of cleavage, as applicable in particular to the roofing-slate of Wales.

In mica-slate, the cleavage is in the direction of the strata of deposition, whether the layers are curved or not; and the same is the case with common clay-slate, and in all depositions of clay which are separable into layers. But in beds of roof-slate, the case is quite different, the cleavage being not in the direction of the strata, but in general obliquely across them. The strata are seldom or never either horizontal or straight, but contorted, bent or waved, and are often far from being parallel with each other.

Why do dikes cause springs? What are the sizes of coal-field dikes?

LIGN. 81.



Slaty structure.

Prof. Sedgwick gives the above diagram, *Lign.* 81, in illustration of this subject, and remarks, "that the contortions of slate-rocks are phenomena quite different from cleavage, and the curved lines presented by such formations, are the true lines of disturbed strata." The contorted lines, running lengthwise of the diagram, are the true strata of deposition, while those crossing these, in nearly a vertical direction, and preserving almost a geometrical parallelism, are the lines of cleavage. A region of more than thirty miles in length, and eight or ten in breadth, exhibits this structure on a magnificent scale. Many of the contorted strata are, of course, mechanical structures; but subordinate to these are fine crystaline chloritic slates. But the coarser beds and the finer, the twisted and the straight, have all been subject to one change. Crystaline forces have rëarranged whole mountain masses of them, producing a beautiful crystaline cleavage, passing alike through all the strata; and through all this region, whatever may be the contortions, the planes of cleavage pass on, generally without deviation, running in parallel lines, from one end to the other.

Without considering the crystaline flakes along the planes of cleavage, which prove that crystaline action has modified the whole mass, we may affirm, that no retreat of parts, no contraction in dimensions, in passing to a solid state, can explain such phenomena as these. They seem to be only resolvable on the supposition, that crystaline or polar forces acted on the whole mass simultaneously, in giving them direction, and with adequate power. The hypothesis that heat, nearly to the melting point, acting as a crystaline force, produced this new arrangement, after the regular deposition of the strata, is the only one which can be suggested to account for these phenomena.

Explain Lignograph 81, and show the difference between the lines of the strata and those of cleavage. How is the cross cleavage of slate accounted for?

CHAPTER XXVIII.

CHEMICAL AND MECHANICAL DEPOSITS.

392. Geologists have made a distinction between mechanical and chemical deposits. By the former, are designated beds of mud, sand, and gravel, produced by the action of running water, as the accumulations in the bottoms, and by the sides of ponds and rivers. But the matter which forms a chemical deposit, has not been mechanically suspended in water, being in a state of solution with the fluid, and separated only by evaporation, cooling, or chemical decomposition. Thus, water flowing from hot springs, and charged with carbonate of lime, constantly deposits its contents in a solid form as the water cools, because it can hold more lime in a hot than in a cold state. Such springs also contain an excess of carbonic acid, in which the lime is also held in solution, and which is deposited as the gas evaporates when coming into the open air. The lime thus deposited, incrusts stones, shells, and wood, at the bottom of the stream, and thus forms a loose porous stone, containing all these matters, known under the names of *travertine* and *calcareous tufa.* Such springs are found in various parts of Italy; and one near Rome deposits large quantities of lime, for many miles in extent, every year. This is so highly charged with lime, that casts are soon formed by exposing molds to the water.

393. *Chemical deposits seldom horizontal.*—The remarks heretofore made on horizontal strata, (379,) do not apply to chemical, but only to mechanical deposits; the latter filling up inequalities at the bottom, by being swept along by the stream; whereas the particles of chemical deposits are consolidated together as they fall, and consequently may incrust the vertical walls of a fissure with equal thickness as that of its bottom. These depositions are generally of small extent, and are confined to limestone districts, as already indicated.

394. *Cementing of Particles.*—It is chiefly in the case of calcareous rocks, that solidification takes place at the

What is the difference between mechanical and chemical deposits? Why are not chemical deposits horizontal?

time of deposition. But there are many deposits, as those of sand, clay, and pudding-stone, in which the cementing process takes place long after their deposition. These rocks, being formed of loose materials, are afterwards consolidated by the percolation of water, containing iron or lime in solution, the finer particles of which, fill up the interstices remaining among the coarser materials of the deposit or accumulation, and thus, from being a soft, yielding mass, the whole becomes a solid rock.

In some rocks, as clay-slate and sandstone, in which fissures are left by contraction, after the strata are deposited, the white seams of carbonate of lime may often be seen traversing the layers in all directions, having filled every fissure, even to the size of a thread. Such examples are common in clay-slate from the quarry near the city of Hartford.

395. *Consolidation under water.*—Mr. Lyell thinks it is probable that some of the heterogeneous materials which rivers transport to the sea, may at once become solid under water, like the artificial mixture called *pussolana*, (Roman cement,) which consists of fine volcanic sand charged with about 20 per cent. of iron, and the addition of a small quantity of lime. This compound hardens under water, and there becomes as solid as stone, and was used by the Romans in constructing the foundations of their buildings under the sea.

Consolidation in such cases is effected by the action of chemical affinity on finely comminuted matter previously suspended in water. After deposition, similar particles seem to exert a mutual attraction on each other, and congregate in particular spots, forming lumps, nodules, and concretions. Thus, in many argillaceous deposits, there may be found calcareous balls, or spheroidal concretions, arranged in layers parallel to the general stratification, an arrangement which must have taken place after the shale or marl had been deposited in layers; for these layers are traced in the concretions, being always parallel to those in the surrounding rock.

396. *Spheroidal, radiated concretions.*—Prof. Sedgwick describes spheroidal concretions, which occur in the magnesian limestone in the north of England. These balls

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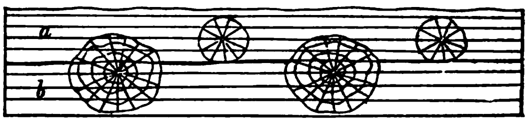
In what manner is loose sand and clay consolidated into solid rock?

are of various sizes, from that of a pea, to several feet in diameter. They have both a concentric and radiated structure, while at the same time the original strata of deposition pass uninterruptedly through them. In some cliffs, this limestone resembles a great irregular pile of cannon-balls. Some of the globular masses have their centre in one stratum, while a portion of their exterior passes through to the stratum above or below.

LIGN. 82.



Concentric balls.

Thus, the larger spheroid in the annexed section, (*Lign.* 82,) passes from the stratum *b*, upwards to *a*. Such phenomena can only be explained on the principle of chemical affinity and crystalization; which, beginning at the centre, must have progressed so as to add the concentric coats around the original nucleus, and at the same time not interfere with the laminated structure of the rocks.

CURVED STRATA.

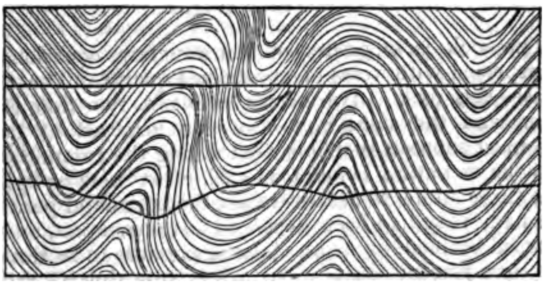
397. We have seen (379) that the original deposition of all strata must have been in the direction of the horizon. But we find, at the present time, that the layers of slate, of various kinds, as those of clay and mica, and also gneiss and stratified limestone, are not only inclined to the horizon at various degrees, but that the strata of some of these rocks are contorted, or bent into crooked or waved lines, clearly indicating that large masses have been moved, in various directions, since their deposition. An experiment was made by Sir James Hall, with a view of illustrating the manner in which such strata, assuming that they were originally horizontal, might have been forced into their present position. For this purpose, a number of layers of clay in a soft state were placed under

What is the explanation of *Lign.* 82? How did Sir James Hall illustrate curved strata?

a weight, and their opposite ends pressed towards each other with such a force, as to cause them to approach more nearly together. On removing the weight, the layers of clay were found to be curved, or folded, so as to bear a miniature resemblance to contorted strata.

On the east coast of Scotland, at a place called St. Abb's Head, Sir James Hall describes a series of contorted strata on a magnificent scale. The rock consists principally of a bluish slate, having frequently a ripple-marked surface. The undulations reach from the top to the bottom of the cliffs, being from 200 to 300 feet in height, and there are sixteen distinct bendings in the course of about six miles. A portion of this is represented by *Lign.* 83.

LIGN. 83

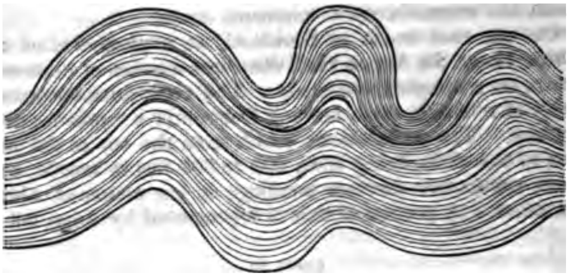


Contorted strata.

398. *Contorted strata at Lyme, Ct.*—In the above instance, the strata are seen on the face of a mural precipice, their general direction, with the exception of the curvatures, being horizontal. To account for their present appearance, therefore, we have only to suppose a pressure at each end of the mountain, adequate to move the two original extremities nearer each other, as in the above-cited experiment of Sir James Hall. In the curved strata at Lyme, (*Lign.* 84,) there must have been an upheaving power, if we assume that the strata were originally horizontal, sufficient to divide the rock, and turn the strata into the vertical position; for although its face is now flat, and nearly horizontal, it consists only of the

edges or ends of the strata contorted, as represented in the figure.

LIGN. 84.



Contorted strata at Lyme.

The rock is of gneiss, of fine structure, occasionally interspersed with veins of crystalized quartz. The road crosses this rock at two places, a mile or two from each other, and the same contortions are exposed at both. We must suppose, therefore, that during the calorific convulsions of nature, before God said, "Let there be light," that these strata were turned from the horizontal position, in which they had been deposited; broken apart, and so softened by heat, as by an endwise pressure to be thrown into their present convolutions. It is true, that all this is mere hypothesis, but since it will serve to explain the appearances, and no one can say it is not true, perhaps there is no harm in believing that it was so.

CHAPTER XXIX.

DENUDATION,

AND THE PRODUCTION OF ALLUVIUM.

399. By *Denudation* is meant the removal of earthy matter by running water, and the consequent exposure of the rocks, which were once covered. This is the precedent of all new accumulations, of mechanical origin, at the

present time. The transport of mud, sand, and stones, by which inequalities on the earth's surface are filled, necessarily implies, that all this matter has only been removed from some other place; and perhaps a gorge has been formed at the place from which it has been transported, much deeper than the one which has been filled. The gain in one place, therefore, shows an equal loss at some other. If, then, the entire mass of stratified deposits, on the earth's surface, is at once the monument and measure of the denudation which has taken place, at unknown periods of time, on what a stupendous scale must the denuding process have been carried on! And accordingly we find, in various parts of the earth, sufficient proofs of the vast extent and power with which running water has acted in producing changes on the crust of the earth.

The earthy matter, thus moved from one place and accumulated in another by occasional floods, is called *Alluvium*. *Diluvium*, as we shall see in another place, refers to similar accumulations, occasioned by the Noachian deluge.

400. It is not difficult to prove, at the present day, that mighty effects have formerly been produced by the action of running water, on the movable materials of the earth. We have here no reference to the solid strata of the earth, but to sand, blocks of stone, and mud, which often evince by their situations, or the forms under which they still exist, the marks of aqueous transport. In many cases, also, by tracing these marks upwards, we can ascertain the places whence they came. Again, where the materials have been so widely spread on a plain as to leave no indications, at the present day, of their ancient removal from another place, still, the sinking of a well, or wells, in the adjoining highland, will often show, by signs not to be mistaken, the denuding effects of water in the vicinity. Hills of considerable height are often formed in this manner, the valley between them having been carried away by some ancient flood.

To make this obvious, suppose that on digging wells on two hills, separated by a valley, there should be found a bed of gravel, ten feet thick, then a layer of clay, then a bed of chalk, then another of clay, and that these forma-

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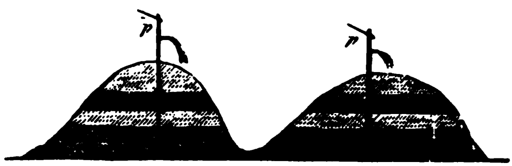
What is meant by denudation? What does an accumulation of earthy matter, in one place, imply in another? What is meant by Alluvium? What is meant by Diluvium?

tions should correspond exactly with each other, both in respect to kind, thickness, and direction; then the inference would be unavoidable, that these strata were once continuous, forming but one extended hill, and that the two hills now existing, are merely divisions of the ancient one, the valley between them being formed by the denuding effects of an overwhelming flood of water, at an unknown period. *Lign.* 85, is designed to illustrate this subject, showing the two hills, with their corresponding strata, and the two wells by which they are pierced. Such examples it is believed are not uncommon, and would often be observed, were due notice taken of the strata, when sinking wells on opposite hills. Where such instances as the above described occur at a distance from rivers, or running streams, and the solid strata show that no such streams ever existed in the vicinity, the excavating power is supposed to have been the general deluge, described in the Scriptures.

LIGN. 85.



Denuding effects of water.

401. *Chasm in New Mexico.*—Perhaps the effects of denudation by running water, no where exists on a more magnificent or terrific scale, than in some parts of New Mexico. The following account is from Mr. Kendall's "Santa Fe Expedition," who describes only what he saw.

Having noticed a tremendous chasm, across which they had great difficulty in making their way, he says: "We came suddenly upon another immense rent, or chasm in the earth, exceeding, in depth, the one we had so much difficulty in crossing the day before. No one was aware of its existence, until we were immediately upon its brink, when a spectacle, exceeding in grandeur any thing we had

How is it shown that valleys and hills are formed by denudation? How deep, and how wide the chasm in New Mexico?

previously beheld, came suddenly in view. Not a tree, or a bush, no outline whatever, marked its position or course, and we were all lost in amazement, as one by one left the double-file ranks, and rode up to the verge of the yawning abyss."

402. "In depth it could not have been less than eight hundred or a thousand feet, and from three to five hundred yards in width, and at the point where we stood, the sides were nearly perpendicular. A sickly sensation of dizziness was felt by all, as we looked down, as it were, into the very depths of the earth. In the dark and narrow valley below, an occasional spot of green relieved the eye, and a small stream of water, now rising to the view, then sinking beneath some huge rock, was bubbling and foaming along. Immense walls, columns, and in some places what appeared to be arches, were seen standing, modeled undoubtedly by the wear of the water; yet so perfect in form, that we could with difficulty be brought to believe that the hand of man had not fashioned them. The rains of centuries, falling on an immense prairie above, had here found a reservoir, and their workings upon the different veins of stone, had formed these strange and fanciful shapes."

The expedition, consisting of several hundred men, with their horses and mules, had no alternative but to descend into this chasm, which it appears extended to unknown distances, both north and south of the place where they were. That there was no other place where it was possible to cross, was proved by the circumstance that all the smaller paths in the vicinity, made by the natives and the bison, terminated in one great road, or thoroughfare, at this point. Having, with great difficulty and danger, descended by an oblique path into this chasm, and followed it to a considerable distance, they found the same path leading out on the opposite side.

403. As they passed along this gorge, objects still more striking and wonderful, were discovered. "In some places," says the author, "perfect walls, formed of reddish clay, were seen standing, which, were they any where else, it would be impossible to believe that other than the hand of man had formed. The veins of which these walls were composed, were of even thickness, very hard, and ran perpendicularly; and when the softer sand, which had sur-

rounded them, was washed away, the veins still remained, standing upright, in some places a hundred feet high, and three or four hundred in length."

"Columns, too, were there; and such was their appearance of architectural order, and so much of chaste grandeur was there about them, that we were lost in wonder and admiration. Sometimes the breastworks, as of forts, would be plainly visible; then again, the frowning turrets of some mighty castle of olden time. Cumbrous pillars, of some enormous pile, such as is dedicated to religion or royalty, were scattered about; regularity was strangely mingled with disorder and ruin, and yet nature had done it all. Niagara has been considered one of her wildest freaks, but Niagara sinks into insignificance when compared with the wild grandeur of this awful chasm." Vol. i. p. 239–40.

CHAPTER XXX.

VOLCANIC ROCKS;

THEIR NAMES, GEOLOGICAL SITUATIONS AND APPEARANCE.

404. HAVING thus given such an account of Aqueous Rocks, (374,) including their composition, names, and form of stratification, as our limits will allow, our attention will next be called to the Volcanic Rocks, which, though not so common as those already noticed, are, in some respects, far more interesting, and especially on account of the tremendous convulsions which nature sometimes undergoes in their production.

We have already stated (363) that these rocks owe their origin, not to water, but to volcanic fire. They appear to be of all ages, from the most ancient to the most recent, and in some countries, are occasionally forming at the present day.

They have either been ejected from burning mountains, or forced up to the surface of the earth in a melted state by internal volcanic action. Some of these rocks are oc-

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What are the comparative ages of volcanic rocks? What are their geological positions?

casionally found superincumbent upon all others, even overlaying the aqueous deposits and fossiliferous strata of the tertiary period; and as volcanoes are still active, they may cover the most recent accumulations of alluvium.

405. *Volcanic rocks produce fertile soils.*—Most of the volcanic rocks produce a fertile soil by their disintegration. It appears that their component ingredients—silex, alumine, lime, potash, and iron—are in due proportions well suited to the growth of vegetables.

406. *Volcanic cones in France.*—In regions where the eruption of volcanic matter has taken place in the open air, and where the surface has never since been subjected to great aqueous denudation, cones and craters are still strikingly characteristic, although ejected at very early periods. Many hundreds of such cones are at the present day the objects of geological interest in the provinces of Auvergne, in France, where they are arranged in lines, and form chains of hills of considerable extent. These ancient volcanoes have been extinct from an early period, there being no historical account of their eruptions, and yet the streams of lava may be traced from the cones to the lowest levels of the valleys below.

407. *Origin of cones and crater-shaped hills.*—The *crater* of a volcano is the circular aperture at the summit of the mountain, from which the flames and fused matter issue during an eruption. The manner in which the cones, as well as the craters of volcanoes are formed, is well understood, the growth of both having been watched, and described by several observers. A chasm, or fissure, first opens in the earth, generally after convulsions and earthquakes have shook the neighborhood, perhaps for days or weeks. From the chasm issue immense volumes of black smoke, attended by steam, flame, and the ejection of red-hot stones and ashes, which are sometimes carried to great heights; the former by the explosive power of the gasses, and the latter by the upward current of the atmosphere, occasioned by the heat. These phenomena having continued for a time, and being often accompanied by convulsions of the earth, and explosions which are heard for many leagues in all directions, there appears melted matter, or *lava*, which quietly runs from the crater

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What soils do these rocks produce? What are volcanic cones? What are craters?

and, forming a stream of liquid fire, slowly descends to the base of the cone, whatever may be its height. If the vol canic cone begins on nearly a level surface, which is sometimes the case, the ejected matter, whether ashes or lava, at first remains near the crater, there being no descent down which the melted stream can run, until a hill, of more or less elevation, has been formed by the action of the volcano itself. The stones and ashes soon accumulate around the chimney, in the form of a *cone*, the centre of which, being kept free from the accumulation, a dish, or *crater*, is formed in the top of the cone, the height of which is sometimes many hundred feet above the point where the gasses and lava first made their appearance.

Sometimes the lava flows over the edge of the crater; at others, this is broken away towards the top, and a notch is formed, through which it passes, and in many instances it flows out of a fissure near the base of the cone.

408. FORMATION OF MONTE NUOVO.—In illustration of our subject, we will give an account of the production of a small volcanic mountain in Italy, which has been described by eye witnesses.

Monte Nuovo, or *New Mountain*, is situated in the vicinity of Naples, a region every where volcanic. It was chiefly thrown up on the night of the 27th of September, 1538. Its site was formerly a little town, where invalids resorted, on account of the thermal baths which existed there, and which were supplied by the hot springs of the place.

On the evening above mentioned, after many previous shocks of an earthquake, the ground opened, in the form of a wide fissure, which ran towards this town, with a tremendous noise and upheaving of the earth, accompanied with the discharge of pumice-stones, blocks of lava, and ashes. At the same time a gulf, of considerable size and extent, opened in the suburbs of the town, and by which several houses were not only broken in pieces, but actually swallowed by the chasm, and entirely disappeared below the ground. The sea at the same time retired, probably by the rising of the land, leaving its former bed naked at some distance from the shore.

The fissure, which had reached the town, there stopped, and began soon after to exhibit all the phenomena of a

From what part of the mountain does the lava first issue?

regular volcano, except the discharge of lava. This continued for the space of only thirty-six hours, since which period there is no record of its having suffered any signs of an eruption. The quantity of matter it vomited forth during this day and a half, was enormous, having formed a regular volcanic mountain in a new situation, 440 feet above the Bay of Naples. The form of this mountain is represented by *Lign.* 86.

LIGN. 86.

Monte Nuovo, near Naples.

Its base, by recent measurement, is found to be 8,000 feet, or about a mile and a half in circumference, and the depth of the crater 420 feet from the summit, so that its bottom is only 20 feet above the level of the sea. No lava flowed from this crater; but the matter ejected, and which fell down and formed the mountain, consisted of masses of ancient lava, ashes, pumice, and slaty stones. These blocks of ancient lava prove the volcanic origin of the ground below the present mountain.

TRAP ROCKS.

409. The word *trap* is from the Swedish *trappa*, which signifies a flight of steps. The rocks now to be described, were so called by Bergman, because they often occurred in tabular masses, with flat surfaces, one above the other, in the form of steps or stairs. This name has been adopt-

What is the origin of the word trap?

ed generally, and now belongs to the nomenclature of science. The family included by this name, are the ancient rocks, chiefly composed of *feldspar*, *augite*, and *hornblend*, and which are considered of volcanic origin, as Basalt, Greenstone, Porphyry, Amygdaloid, Dolerite, and others.

410. *Formation of trap rocks.*—Under what condition the trap rocks were formed, it is now impossible to determine, there being no examples of their modes of production at the present day. We know that fused matter, as it is thrown out of volcanoes, differs in most respects from any of the varieties of this rock; nor do the ancient lavas vary materially from those of the present day—a proof that *age* does not convert lava into trap. The forms under which these rocks exist, also seem to show that they could not have been produced under similar circumstances with the volcanic products of recent origin.

411. Some geologists have supposed that trap was thrown up under the sea, and that the pressure of the water has been instrumental in causing the difference between these rocks and the lava at present ejected. But were this the case, it might be expected that marine products, as shells, would occasionally be found in their fissures, having fallen there after they had cooled, and before they were elevated.

412. *No satisfactory theory of their characters.*—If these rocks were thrown up in the open air, as lava is at this day, and after the elevation of the land from the sea, then we might inquire how products having the same origin, and under similar circumstances, should differ so materially in texture and appearance, the trap being solid, while the lava is always porous, sometimes even floating on water. Besides, the lava is commonly spread out in thin sheets, as it runs in the liquid state from the mountain; while the trap, in most of its varieties, is in the form of steps, as its name indicates. It appears, therefore, that in the present state of knowledge, no satisfactory solution can be given why these rocks, which all geologists agree were once in a state of fusion, should assume characters so distinct from the volcanic products of the present time.

What is the composition of trap rocks? What rocks belong to the trap family? What is said of the origin of trap?

BASALT.

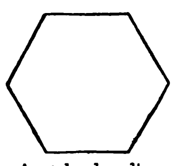
413. The color of this rock is dark grayish black, or brownish gray. It is found both in large, shapeless masses, and in columnar prisms, with from three to nine sides, or faces. These columns are of all sizes, from a few inches to several feet in diameter, and sometimes 300 or 400 feet in height. They are composed of joints, or blocks, of the same angular shapes, resting on each other, and standing in rows, or clusters, sometimes consisting of several hundreds in the same range, or group.

The texture of basalt is fine-grained, or compact, and it often contains other minerals imbedded in it, as feldspar, quartz, mica, leucite, and oxyd of iron. It also exhibits hollow cavities, or vesicles, apparently formed by bubbles of air during its fusion.

414. Columnar Basalt.—All the members of the Trap family occasionally assume the form of columns, more or less perfect, but in this respect basalt excels the others.

These columns appear to have been formed by a natural and crystaline division of the whole mass of basalt, after its elevation to the surface. This division being vertical, the columns stand, when not since disturbed, in nearly a perpendicular direction. They vary in the number of their angles and sides, from three to eleven or twelve, the medium number being from five to seven. These are often perfectly regular, the angles being sharp and well defined, with plane and smooth faces, as represented by the outline *Lign.* 87

LIGN. 87.



Angular basalt.

415. In most cases, when standing in their original positions, their sides are in contact, or nearly so, the an-

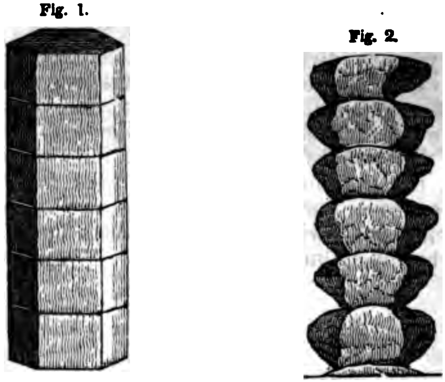
What is the color of basalt? To what family does basalt belong? Describe columnar basalt.

gles of one column so exactly fitting the matrix made by several others, as to prove that the whole were once a single mass, the separation being only in consequence of the crystaline process, which gave each its present angular form. The columns are sometimes longitudinally continuous for the distance of many feet, and at others, separated into blocks by joints, which are mostly horizontal, and which appear to have been effected by crystaline arrangement.

The appearance of a six-sided basaltic column, regularly jointed—that is, consisting of short prisms, laid on each other—is represented by *Lign.* 88, *Fig.* 1. It is not common, however, that the prisms are as regular, with respect to length, as here represented, the joints being mostly repeated at intervals, varying from a few inches to several feet.

LIGN. 88.

Fig. 1. Fig. 2.



Basaltic columns.

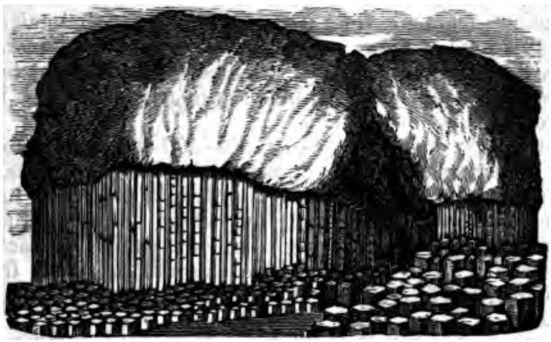
In exposed situations, the prismatic blocks, represented above, often loose their angles by the action of the weather, and become irregular, sometimes approaching the globular form, but still retaining their columnar position, as shown by *Lign.* 88, *Fig.* 2.

It must not be understood that these basaltic columns

Are basaltic columns the effect of crystalization, or not?

generally preserve their vertical positions, as usually represented by the drawings of Staffa, and the Giant's Causeway, these being rare instances, both with respect to position and height. These columns are found in every position, from the horizontal to the vertical. *Lign.* 89 represents Fingal's Cave, on the island of Staffa, one of the Western islands of Scotland. Many of the basaltic columns have fallen down. The round massive cap is basaltic.

LIGN. 89.



Fingal's cave at Staffa.

416. TRAP MOUNTAINS.—Trap rocks often form mountains of considerable height, and which sometimes spread over large districts of country. The island of Skye, on the western coast of Scotland, is one continuous mass of erupted matter, 50 miles long and 20 broad. With respect to the elevation of these mountains, the following are examples: Mount Tinto, in the district of Clyde, is 2,036 feet high; Benmore, on the island of Mull, 3,097; Salisbury Craig, Scotland, 550, and Arthur's-seat, near Edinburgh, 800 feet.

On this side of the Atlantic, Mount Holyoke, in Massachusetts, is 900 feet above the level of the sea, and Mount Tom, on the opposite side of the Connecticut, is nearly 1,000 feet high. A portion of the trap rocks at Mount Holyoke assumes the columnar structure, but they appear to differ from the true basalt, in being lighter in

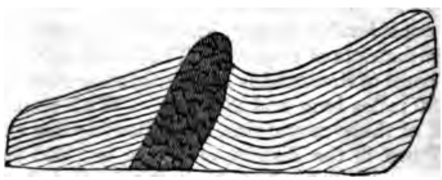
What are the heights of the basaltic mountains mentioned? What is the difference between basalt and greenstone?

color, and in wanting the vesicles usually seen in broken specimens of foreign basalt. It is considered a Greenstone rock. Perhaps *Basaltic Greenstone*, in view of its columnar appearance, would be a better name.

417. Greenstone.—This is a compact, hard, tenacious trap rock, of a dark grayish color, with a greenish tinge, and hence the name. It is essentially composed of hornblend and feldspar. This rock occurs in beds of greater or less extent, sometimes forming extensive ranges of mountains. In this country, greenstone is a common rock, the range of mountains on the west side of the Connecticut, reaching from New Haven to Northampton, is of this kind. These rocks, as we shall see in another place, are undoubtedly of volcanic origin, having been elevated to the present situation, through fissures, by the force of subterranean fire.

418. *Protrusion of greenstone.*—Although greenstone, as belonging to the trap family, is considered of volcanic origin, and passes insensibly into basalt, still there have been but few instances detected, where it has protruded through superincumbent rocks, so as to exhibit the fact to the eye of the geologist. The diagram, *Lign.* 90, from Hitchcock's Geology of Massachusetts, presents such a case.

LIGN. 90.



Protrusion of greenstone.

"The protrusion," says the author, "of the unstratified rocks, through the stratified ones, by internal igneous agency, now admitted by most geologists, has led observers to examine carefully for evidences of mechanical disturbance, near the line of contact. They have, I believe, found less proof of such disturbance by the intrusion of greenstone,

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What is the composition of greenstone? What does *Lign.* 90 represent?

than in the case of the older rocks, as sienite and granite. Every such case, therefore, deserves to be noticed. If I mistake not, the following sketch of a vein of greenstone, in argillaceous slate, is an example of this sort. The dike is about ten feet thick, and the general dip of the layers of slate in the quarry, is about 30° south-east. But, as shown in the figure, near the greenstone, it is considerably curved upwards, in the contrary direction. The quarry where this example occurs, is about half a mile north of the powder-house, in Charlestown, Mass."

419. SIENITIC GREENSTONE.—The highly crystaline compounds which compose greenstone, feldspar, and hornblend, having a granitic texture, with occasionally a portion of quartz intermixed, is called Sienitic greenstone; a rock which passes into ordinary trap, on the one hand, and into granite on the other.

420. TRACHYTE.—The name comes from the Greek *trachus*, rough, because it is peculiarly harsh to the touch. This is a porphyritic rock, of a whitish or grayish color, composed principally of glassy feldspar, with crystals of the same, generally with hornblend and oxyd of iron.

421. PORPHYRY.—The name is from the Greek, signifying *purple*, because the first rocks so called had a purple color. At present, however, any rock having a compact or paste-like base, with imbedded crystals, is called by this name, whatever its color may be. Porphyry has the appearance of once having been in the form of a soft paste, into which crystals of various kinds, but most commonly feldspar, have, by some unknown means, been introduced. When associated with granite, this is considered a primitive rock, but it sometimes is found with secondary, or hypogene, and then again with volcanic rocks. It may, perhaps, be viewed as the connecting link between granitic and volcanic productions.

422. *Ancient Monuments of Porphyry.*—The columns of some of the most ancient and splendid edifices, were made of this material, of which some polished remains are still existing. The great hardness of this rock, being chiefly composed of silicious matter, the high polish it is capable of receiving, and the variety and beauty of the colors it

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What is sienitic greenstone? What does trachyte mean? What is the meaning of porphyry? What peculiarities has porphyry?

often presents, afford a combination of qualities for splendid and enduring architectural purposes, which is found in no other mineral body. But the labor of forming pillars of this rock, 30 or 40 feet high, and 5 or 6 feet in diameter, such as the ancients constructed, is much too great for the present age.

Porphyry, though not an uncommon rock, never occurs in extensive formations, like limestone and granite.

423. AMYGDALOID.—The name is from the Greek, *amygdala*, an almond, from the oval-shaped nodules it contains. This is another of the trappean family, and in texture presents more obvious proofs of its igneous origin, than any of the others.

424. The origin of its structure may be traced in modern lava, in which pores or cells, formed by bubbles of air, or steam, are common, while the matter is in the melted state. These are elongated by the flow of the lava, while it is yet soft, and thus these bubble cavities become oval, or almond-shaped. After this igneous product has consolidated by cooling, these cavities still remain, and the whole being porous, are filled by the infiltration of silicious or calcareous matter. In some amygdaloids, these nodules have decomposed by exposure, when the empty cells present the same glazed or vitreous coating that is seen in the slags of furnaces.

425. LAVA.—This term is said to come from the Gothic, signifying *to run*, in reference to the flowing of volcanic matter; and this application is retained to the present day, although volcanic products present a great variety in appearance and composition. This general term for all the liquefied products of volcanoes, therefore includes those which are distinguished by several names, as *volcanic slags*, *volcanic enamel*, *cellular lava*, *compact lava*, *pumice*, &c. The colors of lava are commonly yellowish, or greenish gray, sometimes running into sulphur yellow and grayish black. Some are quite compact, and receive a fine polish, while others are full of small pores; and others are fibrous, with a silky lustre; but all the different kinds run into each other. Pumice is sometimes so full of air-cells as to swim on water; the vicinity of subma-

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What does amygdaloid mean? How is this rock formed? What does lava mean, and to what products is it applied?

rine volcanoes having often been indicated to sailors by this circumstance.

IGNEOUS ORIGIN OF TRAP ROCKS.

426. Although, in the foregoing pages, it has frequently been intimated that the trappean rocks were of supposed igneous origin; yet, with the exception of the single instance of the protrusion of greenstone, (418,) we have produced no evidence that this was the case. It is true, as already noticed, (412,) that no satisfactory reason can be shown, why these rocks differ so materially from the volcanic products of the present time, if, indeed, they have had a common origin. But it may be remembered, that we know nothing of the circumstances under which they were produced; and were the contrary the case, perhaps the solution would be in no degree facilitated; since, at the present time, we see that volcanic products, thrown out of the same crater, and at the same time, differ as much in appearance, texture, and composition, as lava does from any of the trap rocks, and yet no one can solve the question why this is so.

427. *Proofs of the fusion of trap rocks.*—The igneous origin of trap, especially of basalt and greenstone, is proved by the fact, often observed, that when they come into contact with the strata of other rocks, in their passage from below, towards the surface of the earth, the effects of heat are always apparent on such strata.

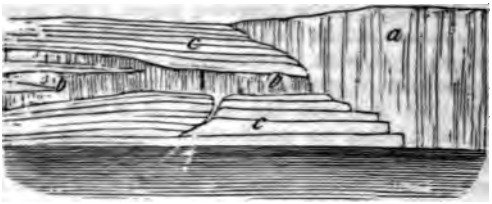
428. *Effects of a basaltic dike on coal.*—When a dike of basalt intersects a stratum of coal, the latter, to the distance of several feet, or even yards, is deprived of its bitumen, and converted into *coke.* And it may be stated, as a well-known fact, that the effect of a basaltic dike on the contiguous strata, is precisely that which would have been produced, had the matter of the dike been at a red, or even a white heat, at the time of its protrusion.

429. *Protrusion of trap between strata.*—But there are other circumstances which show that basaltic dikes were formed in a fluid state; for when these penetrate stratified formations, the matter of which they are composed sometimes insinuates itself between the strata from beneath, in a manner which would be impossible, had it not been in that state. Dr. Macculloch, in his *Geology of the Western*

How is the igneous origin of trap proved by its effects on coal?

Isles, illustrates this point by a diagram, which we copy, *Lign.* 91.

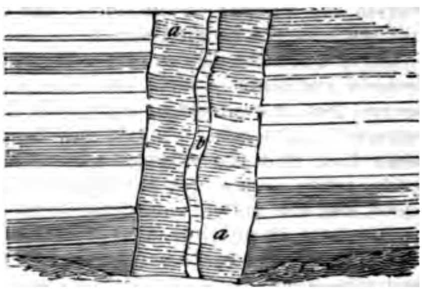
LIGN. 91.



Protrusion of basalt.

The rock is stratified sandstone, which the fused basalt has pierced from below. The vertical lines, *a*, represent the basalt, partly incumbent in the unconformable position on the horizontal strata *c*, *c*. At *b*, *b*, the basalt has forced up the sandstone, and passed between the strata, two of which it has entirely separated from their fellows, forming between them sheets of its own matter.

LIGN. 92.



One vein of basalt piercing another.

430. *One dike of basalt pierced by another.*—In some instances, a large vein of basalt is pierced by a smaller one, which, passing through its middle, divides it into two parts. Such an instance is represented by *Lign.* 92, from *Dr.*

What geological fact is proved by *Ligns.* 91 and 92.

Ure's Geology. The great basaltic dike *a, a,* passes through calcareous sandstone, and *b*, a small vein of the same matter, has passed through its axis. It is most probable that the dike first made its way through the sandstone, and on cooling, was fissured through the middle, and that this was filled by a second eruption of liquid basalt from beneath.

431. *Basaltic veins formed from above.*—Although, in nearly every instance observed, the veins of trap appear to have ascended from below towards the surface, still it seems that there are cases where the fused matter has come in the contrary direction. This rare phenomenon occurs in the island of Skye, one of the western isles of Scotland, and is described by Dr. Macculloch.

LIGN. 93.

Basaltic veins from above.

The basaltic veins traverse the sandstone strata in a vertical direction, and parallel to each other. The mass, above the vertical lines, *Lign.* 93, which are the basaltic veins, is basalt, and from which the veins appear to have descended; and they are so numerous in some places, as nearly to equal, taken collectively, the mass of rock through which they pass. Sometimes six or eight veins occur within the space of 150 feet, and their aggregate magnitude is apparently 60 or 70 feet. Their average breadth is about ten feet, though they vary from five to twenty feet.

What rare fact is shown by *Lign.* 93.

It is certainly very difficult to account for the manner in which nature performed this work. Were the veins only an inch or two thick, we might suppose that the melted trap ascended by the large middle vein, seen in the drawing, and having fissured the sandstone by its great heat, descended again by the apertures thus produced; but the fissures are much too large for such a supposition.

It is supposed that every basaltic dike terminates in a mass of the same matter below the surface; and, therefore, that the rocks, resting on the surface, are connected by these veins with the mass beneath; so that such dikes and veins are necks, passing through the crust of the earth from one to the other.

CHAPTER XXXI.

PLUTONIC ROCKS;

THEIR ORIGIN, NAMES, COMPOSITION, AND APPEARANCES.

432. WE have already (364) given a general account of the Plutonic rocks; stated that they were formerly called *primitive*, and have given the reasons why this name has been changed, (359.)

GRANITE.

This is the principal rock in the Plutonic class, and is so called because it consists of *grains*. It is, as already stated, (364,) composed of *feldspar*, *quartz*, and *mica*, all of them in the crystaline form, and in the coarse-grained varieties, quite distinct from each other. Their colors are also very different, that of the quartz being more commonly white, that of the feldspar, yellowish or flesh-colored, and that of the mica, black. These colors, however, vary in different rocks, the quartz being sometimes rose-colored, the feldspar milk-white, and the mica also white, and in thin plates, as transparent as glass.

The ingredients of granite all occur in crystals, under

What is the principal rock in the Plutonic class? What are the ingredients of granite? What are the colors of these ingredients?

favorable circumstances; but in the production of this rock, the crystalization is confused, because the particles of each have no room to assume their determinate forms.

Granite never occurs in layers, like mica-slate and gneiss; and being crystaline in its texture, is sometimes called *unstratified crystaline rock.*

The components of this rock, not only differ widely with respect to the proportions of each, but also in their sizes; in some granites the crystaline masses being nearly a foot in diameter, while in others, the grains are little larger than those of sand.

IGNEOUS ORIGIN OF GRANITE.

433. Geologists formerly believed that granite was of aqueous origin; that is, that the materials of which it is composed, were first dissolved in water, as preparatory to their assuming that solid and crystaline form which it presents at the present time. Chemistry has long since taught us that no substance in the laboratory of art, nor, so far as is known, in that of nature, ever assumes the crystaline form until it has been dissolved in some fluid; and, indeed, a single consideration will show, beyond all question, the necessity of such a solution; for otherwise, there could be no motion among the particles of which the crystal is composed; and without free motion, it is equally certain that these particles could never take their places according to the laws of affinity; in other words, never could assume the crystaline forms.

434. *Different substances require different solvents.*—The kind of fluid in which the particles are dissolved, it is obvious, must depend on the nature of the substance. Thus, some are soluble in water, others in alcohol, and others in caloric. Now, although the materials composing granite, are nearly insoluble by artificial means, still, there is no doubt that, under a very high temperature, with the aid of pressure, they would be soluble in water, or in caloric alone; and the phenomena, as we shall see, afford conclusive evidence that the latter was the solvent, and that the materials composing granite were once in a state of fusion.

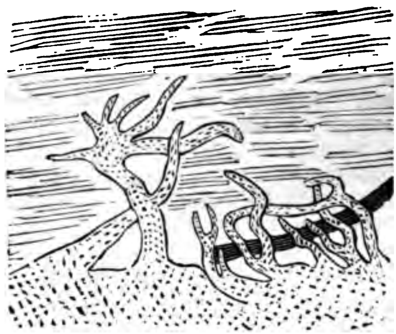
435. *The igneous origin of granite proved.*—The igneous

What was formerly believed to have been the origin of granite? Does any substance crystalize without solution? What was the solvent of granite?

origin of granite is satisfactorily proved from the phenomena of its veins; from the calorific effects of these veins on the walls of the rocks through which they have protruded; from the intrusion of granitic matter between the strata of various rocks, through which such veins have been forced; and, lastly, from the passage of known igneous rocks into granite.

436. *The phenomena of trap and granite exactly similar.*—Having already shown (427) the undoubted igneous origin of *trap* rocks, by proving that their matter, when in the soft state, was forced between the strata of other rocks, (*Lign.* 91,) we shall now show that the same phenomena are found to attend the veins of granite whenever they traverse other rocks; there being every indication that these veins were also forced up from below, in a state of fusion.

LIGN. 94.



Protrusion of granite into mica-slate.

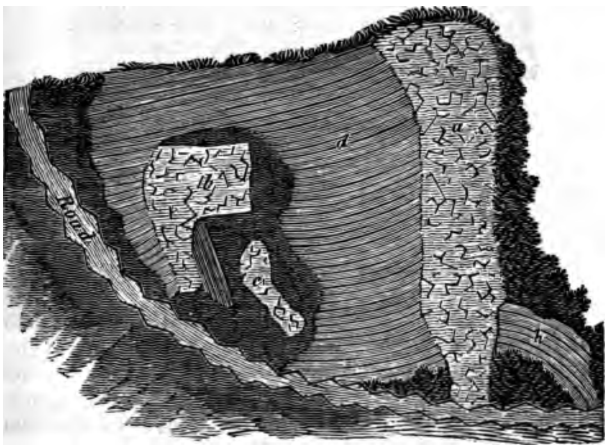
Such an instance is represented by *Lign.* 94, which, according to Dr. Macculloch, occurs at Cape Wrath, in Scotland. The strata through which the veins pass, are of gneiss, and it will be observed, that they intersect each other in various directions, being curiously branched and contorted, resembling so many snakes crawling from their den. The mass of granite below the stratified gneiss, is also apparent; and as the veins end before reaching the surface, we cannot but infer that they were forced up in a

How is it proved that granite was once in a state of fusion?

softened state from the underlaying granite, with which their trunks are incorporated. Similar instances, that is, of granite veins traversing stratified rocks, and also granite rocks, are known to occur frequently.

Dr. Hitchcock, in his *Report of the Geology of Massachusetts*, has described and figured many such instances, two of which we take the liberty of inserting.

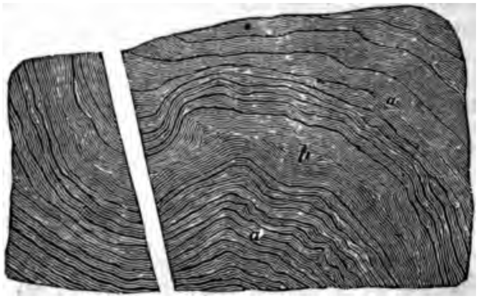
LIGN. 95.



Protrusion of granite into hornblend.

437. *Granite protruding through hornblend-slate.*—The first occurs at Ackworth, New Hampshire, where a dike or vein of granite protrudes through strata of hornblend-slate, *Lign.* 95. As the traveler approaches the spot, says the author, he will observe, while several miles distant, a remarkable conical, half-naked peak, chiefly of white granite, shooting up about 300 feet above the surrounding country. The prevailing rock in this vicinity is gneiss; but at this elevation it is chiefly hornblend-slate, traversed by an enormous vein of granite, *a*, and exhibiting two other protruding masses of the same, at a distance from it, *b* and *c*. The vein *a*. varies from one-half to four rods in thickness, and the mass *b* is four or five rods across; *c* is only ten feet wide.

LIGN. 96.



Granite passing through mica-slate.

438. *A vein of granite passing through mica-slate.*—The other occurs in Conway, Massachusetts, where the mica-slate, in nearly a perpendicular ledge, is represented by *Lign.* 96. The white vein shows the granite passing through, without disturbing the slaty structure.. It is fine-grained, and about a foot wide.

The object of giving this sketch, says the author, is to show that this vein has produced no derangement of the mica-slate; for the different particles of that rock occupy the same relative position on both sides of the vein; hence, it is concluded that the granite was introduced after the consolidation of the slate, and probably was injected into an open fissure.

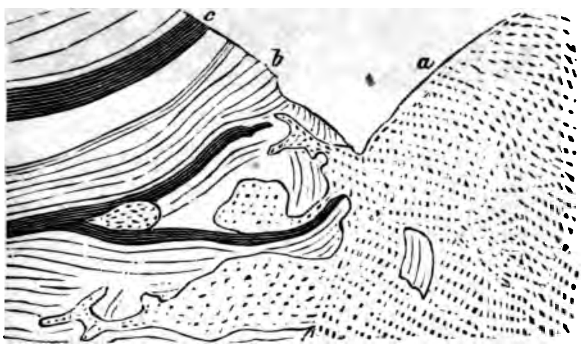
PASSAGE OF GRANITE INTO BASALT

439. Dr. Hibbert describes the manner in which granite gradually passes into basalt, in one of the Shetland islands. The ranges of the two rocks extend several miles, and are perfectly distinct. Near the place where they meet, the author says, that the basalt may be observed to contain many particles of quartz, this being the first indication of the approaching change in the nature of the rock. Nearer the granite these particles increase and grow larger; and the rock is gradually so changed as to consist of *quartz* and *hornblend*, *feldspar* and *greenstone*, the latter being a homogeneous mixture of hornblend and feldspar. Again, as we approach still nearer the granite, the disseminated portions of greenstone disappear, their place being supplied

by an additional quantity of feldspar and quartz. The rock now consists of three ingredients—feldspar, quartz, and hornblend. The last change which takes place, results from the still increasing accumulation of quartz and feldspar, and the hornblend entirely disappears, and we have a well-characterized granite, consisting of quartz and feldspar.

440. *Intrusion of granite into limestone.*—At Glen Tilt, in the Grampian hills, Scotland, the veins of red granite are seen branching out in all directions from the principal mass, and meeting the contiguous slate and limestone rock. The granite veins intermingle with, and disturb the strata of the other rocks, in such a manner as to prove not only that the former was in a fluid state at the time of its intrusion, but also that it was forced up with great violence.

LIGN. 97.



Intrusion of granite into limestone.

The diagram, *Lign.* 97, from Dr. Macculloch, represents the appearance of these rocks. "The granite at this locality," says Mr. Lyell, "often sends forth so many veins as to reticulate with the limestone and slate, the veins diminishing towards their termination, to the thickness of a leaf of paper or a thread. In some places, fragments of granite appear entangled in the limestone, and are not visibly connected with any large mass; while sometimes, on the other hand, a lump of the limestone is found in the midst of the granite. The granite is marked *a*, the limestone *b*, and the slate *c*. The ordinary color of the limestone at

Glen Tilt, is lead blue, and its texture large grained; but where it approaches the granite, particularly where it is penetrated by the smaller veins, the crystaline texture disappears, and it assumes an appearance exactly like hornstone, a change obviously owing to the heat of the intruding mineral."

These proofs are considered sufficient to show the igneous origin of granite, though an abundance of others might be adduced from authors.

LIGN. 98.

Porphyritic granite.

441. Porphyritic Granite.—This name is applied to that variety of granite, which has a fine texture, with crystals of feldspar, sometimes an inch or two in length, scattered through it. When the color of the base is dark, with an intermixture of black mica, this compound has quite a curious, and sometimes a striking appearance. Some polished specimens of this sort are exceedingly beautiful. An example of this variety, from Cornwall, figured in *Lyell's Elements*, is represented by *Lign*. 98.

442. Sienite.—This is so called from the celebrated ancient quarry of Syene, in Egypt, where it is said this variety is found. It is composed of quartz, feldspar and hornblend, being a granite in which the mica is replaced by hornblend. It is commonly fine-grained, and has all the appearance of ordinary granite; nor can it be distinguished from it, except by so close an inspection as to observe the difference between the crystals of mica and those of hornblend. It is said to pass insensibly into sienitic

What is porphyritic granite? How does sienitic differ from common granite?

greenstone by the loss of its quartz, which is a rock of the trap family, composed of feldspar and hornblend.

443. SERPENTINE.—The color of this rock is sometimes green, black, and white, in crooked stripes, or *serpent-like*, and hence the name. Serpentine occurs in both divisions of the hypogene rocks, being sometimes stratified, when it belongs to the *metamorphic* class; and when unstratified, it is a *plutonic* rock. The pure varieties of this mineral, called *noble* serpentine, consist of hydrated silicate of magnesia, generally of a greenish color. The common varieties are mixed with steatite, or soapstone and talc. These minerals are unctuous, or soapy to the touch, in consequence of the magnesia in their composition.

Serpentine often passes into steatite, and this into talc, or what is known under the name of French chalk, the latter being only a crystaline variety of soapstone. It is well known that the last-named mineral is in common use for domestic purposes, as the linings of stoves and fireplaces, being uninjured by common degrees of heat.

444. TALCOSE SLATE.—This belongs to the soapstone family, talc being the essential ingredient, but it is ordinarily mixed with more or less quartz and mica, and sometimes with feldspar and hornblend. It is of a greenish color, and unctuous to the touch. This family, though not uncommon, are never found in extensive strata, forming mountains.

CHAPTER XXXII.

METAMORPHIC ROCKS;

THEIR GENERAL CHARACTERS, ORIGIN, NAMES, AND COMPOSITION.

445. HAVING thus given such an account as our limits will allow of the three great classes of rocks, the Aqueous, or Fossiliferous, (366); the Volcanic, (404); and the Plutonic, or Granitic, (432); we now come to the fourth

Why is serpentine so called? To what class does serpentine belong What is the common name of steatite?

and last grand division, the Metamorphic Rocks. These consist of what were formerly called the ***stratified primary*** rocks, as gneiss, mica-slate, and others, (365.)

These rocks deposited from water, and changed by heat.—Mr. Lyell, the author of this arrangement, says: "According to the theory which I adopt as most probable, the materials of these strata were originally deposited from water in the usual form of sediment, but they were subsequently altered by subterranean heat, so as to assume a new texture. It is demonstrable, in some cases at least, that such a complete conversion has actually taken place. I have already remarked that alterations, such as might be produced by intense heat, are observed in strata near their contact with veins and dikes (427) of volcanic rocks. These, however, are on a small scale; but a similar influence has been exerted much more powerfully in the neighborhood of Plutonic rocks under different circumstances, and perhaps in combination with other causes. The effects thereby superinduced on fossiliferous strata, have sometimes extended to the distance of a quarter of a mile from the point of contact. Throughout the greater part of this space the fossiliferous beds have exchanged an earthy for a highly crystaline texture, and have lost all traces of organic remains. Thus, for example, dark limestones, replete with shells and corals, are turned into white statuary marble, and hard clay into slates, called mica-shist and hornblend-shist—all signs of organic bodies having been obliterated." El. p. 22.

446. *Hypothesis of the conditions which produce such changes.*—"Although," continues Mr. Lyell, "we are in a great degree ignorant of the precise nature of the influence here exerted, yet it evidently bears some analogy to that which volcanic heat and gasses are capable of producing; and the action may be conveniently called plutonic, because it appears to have been developed in those regions where plutonic rocks are generated, and under similar circumstances of pressure in the depth of the earth. Whether electricity or any other causes have cöoperated with heat to produce this influence, may be matter of speculation, but the plutonic influence has sometimes per·

What is supposed with respect to the deposition of the Metamorphic rocks? Under what circumstances is it supposed that fossiliferous rocks have been changed into mica-slate and gneiss?

vaded entire mountain masses of strata. The phenomena, therefore, being sometimes on so grand a scale, we must not consider that the strata have always assumed their crystaline, or altered texture, in consequence of the proximity of granite, but rather that granite itself, as well as the altered strata, have derived their crystaline texture from plutonic agency."

447. *Fossiliferous strata converted into metamorphic rocks.*—That the rocks known under the name of gneiss and mica-slate, were originally deposited from water, their slaty structure fully proves, since strata can have been formed by no other means but deposition. Now, gneiss and mica-slate are composed of the same materials as granite, viz: quartz, feldspar, and mica, though in the former the feldspar is usually less in proportion than in granite, and in mica-slate the feldspar is often nearly or quite absent, an additional quantity of mica taking its place. These rocks are always, or most commonly, found associated with granite, as shown by *Lign.* 71.

448. *Can clay-slate and limestone be converted into gneiss and mica-slate ?*—This question very naturally arises from what has already been stated. We cannot here go into a description of all the chemical changes which must take place in the conversion of one of these rocks into the other; but simply remark, that clay-slate is chiefly composed of aluminous earth and silex, and limestone, of lime and carbonic acid. Mr. Lyell states, "that a texture undistinguishable from that which characterizes the more crystaline metamorphic formations, has actually been superinduced in strata once fossiliferous." El. vol. ii. p. 402.

In proof of such a change, the author cites the following facts, which occur near Christiana, in Norway, where granite protrudes in mountain masses through fossiliferous strata. The stratified rocks, replete with shells and zoophytes, consist chiefly of shale, limestone, and sandstone; and all these are invariably altered by the granite, for a distance of from 50 to 400 yards. The aluminous shale is hardened, and has become flinty, sometimes resembling jasper. Ribboned jasper is produced by the hardening of alternate layers of green and chocolate-colored slate, each stripe faithfully representing the original lines of stratification. Nearer the granite the shist often con

tains crystals of hornblend, which were met with in some places, for a distance of several hundred yards from the junction; and this black hornblend is so abundant, that eminent geologists, when passing through the country, have confounded it with the ancient hornblend-shist, subordinate to the great gneiss formation of Norway. Frequently, between the granite and the hornblendic slate, above mentioned, grains of mica and crystaline feldspar appear in the shist, so that rocks, resembling gneiss and mica-slate, are produced. Fossils can rarely be detected in these slates, and they are more completely effaced in proportion to the more crystaline texture of the beds, and their vicinity to the granite. In some places the silicious matter of the slate has become a granular quartz; and when hornblend and mica are added, the altered rock loses its stratification, and passes into a kind of granite. The limestone, which is at points remote from the granite, is of an earthy texture, blue color, and often abounds in corals, becomes a white granular marble near the granite, sometimes silicious, the granular structure extending occasionally upwards of 1,200 feet from the junction; and the corals being for the most part obliterated, though sometimes preserved, even in the white marble. Both the altered limestone and hardened slate contain garnets in many places; also, ores of iron, lead, and copper, with some silver.

From these, and other facts of a similar nature, Mr. Lyell assumes, "that powers exist in nature, capable of transforming fossiliferous into crystaline strata; powers capable of generating in them a new mineral character, similar—nay, often absolutely identical—with that of gneiss, mica-shist, and other stratified members of the hypogene series."

Having thus explained Mr. Lyell's theory of the changes which the hypogene rocks have undergone, showing that what are now gneiss and mica-shist, were once clay-slate or sandstone, we will proceed to notice some of the individuals of this class.

449. The chief members of the metamorphic series, are *gneiss*, *mica-shist*, *hornblend-shist*, *clay-slate*, *chlorite-shist*, and *metamorphic limestone*. [We use the word *slate* when

What are the members of the Metamorphic series? What is the difference between shist, and slate?

the mineral is fissile, but when the structure, though slaty, is not divisible into thin layers, *shist* is used.]

450. GNEISS.—This rock may be considered stratified granite, being formed of the same materials, namely, quartz, feldspar and mica. The strata are often imperfect, the layers running into each other. The materials are not promiscuously intermingled, as in granite, but are aggregated together; and each commonly having a different color, the rock has a striped appearance, especially when broken across.

LIGN. 99.

Metamorphic rock, gneiss.

A specimen of this rock is represented by *Lign.* 99, and which gives a good idea of its most common appearance. In this specimen, the white layers consist of granular feldspar, with here and there a speck of mica and a grain of quartz. The dark layers are composed of gray quartz and black mica, with occasionally a grain of feldspar intermixed. The rock splits most easily in the plane of these darker layers, and the surface thus exposed is almost entirely covered with shining spangles of mica. As already stated, (447,) this rock is nearly always associated with granite, and probably the heat by which it has acquired its present form and texture, was communicated from that rock.

451. MICA SHIST.—This, next to gneiss, is the most abundant of this series of rocks. It is chiefly composed of mica and quartz, the feldspar being only in small quantities, or in some instances quite absent. The quartz is usually in fine grains, and the mica usually predominates, or, at least, is much the most apparent, some specimens

What is the composition of gneiss? How does gneiss differ from granite? How does mica-slate differ from gneiss?

being chiefly composed of small scales of mica, closely adhering together. It is much more distinctly stratified than gneiss, and where the mica is abundant between the layers, is easily split into slabs.

At Bolton, Ct. is an extensive quarry of mica-shist, from which large quantities are taken, chiefly for the purpose of flagging the side-walks of cities. The flaggings of the city of Hartford, often present these strata, measuring 12 or 14 feet in length, by 8 or 10 wide, and only four or five inches thick, and perfectly level. These are split at the quarry, and are so perfect in all respects, as only to require the chisel to trim the edges. The strata at this quarry, where the best specimens occur, are nearly perpendicular. Gneiss is intermediate between granite and mica-shist in its structure, and is often interposed between these rocks, lying over the former and under the latter, (*Lign.* 71.) Indeed, these rocks pass by insensible grades into each other, the gneiss passing into granite by losing its stratified structure, and into mica-shist by becoming fissile. This rock often contains garnets, very perfectly formed, with twelve sides, and of a reddish color.

452. HORNBLEND-SHIST.—This is composed principally of hornblend, with a variable quantity of feldspar, and sometimes grains of quartz. It is usually of a dark or black color; and when the hornblend and feldspar are nearly in equal quantities, and the rock is not slaty, it corresponds in character with greenstones of the trap-family, (417,) and has been called "primitive greenstone."

453. CLAY-SLATE, ROOF-SLATE.—The soft, yellowish clay-slate is an aqueous deposit; while the roof-slate is found among the primitive or metamorphic rocks. It usually is of a dark or slate-color, exceedingly fissile, being readily split into layers of only a quarter of an inch in thickness. It is well known as a roofing-slate, and is also in extensive use, as a graphic, or writing-slate for schools.

454. CHLORITE-SHIST.—This is a green slaty rock, in which the simple mineral, chlorite, so named on account of its green color, is the essential ingredient, and occurs in the form of foliated plates. It is commonly blended with grains of quartz, and sometimes with feldspar and mica. It never occurs in such quantities as to form mountains.

What is the composition of hornblend-shist? What is the appearance of chlorite-shist?

CHAPTER XXXIII.

RELATIVE AGES OF THE FOUR CLASSES OF ROCKS.

455. We have now named and described, separately, all the principal members of each of the great classes into which geologists of the present day divide the Mineral Kingdom. But the subject of rocks, though treated of in all other respects, cannot be considered as finished until something, either by way of facts or conjectures, be offered with respect to their relative ages. Of the actual epoch of their creation—that is, when "God created the heavens and the *earth*"—of course, we know nothing. This, the Mosaic history informs us, was in the "*beginning*;" and we must believe, however remote might have been that period, that all the materials of which the earth consists, were brought into existence at that time; since there is no account of the creation of any inorganic matter, belonging to our earth, at any subsequent period. These materials, as we shall more particularly show hereafter, have undergone great, and, in many instances, repeated changes among themselves, and with respect to each other. But the actual periods of time, when these ancient changes were effected, were too remote even for conjecture, and therefore it would be useless to speculate on that point. The period, however, at which the rocks assumed their present relative positions—that is, which first took its present situation with respect to the others—is a question which can often be decided by the indications of the rocks themselves; and this is the subject of the following observations.

AGES OF THE AQUEOUS ROCKS.

456. It will be quite apparent, that with respect to the relative ages of a series of horizontal strata, lying in the position in which they were deposited, the lower stratum must be the oldest, and the upper newest. Each layer in such a formation was once the uppermost, whatever situation it may now occupy with respect to the others. The

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How are the ages of horizontal strata determined with respect to each other?

lowest stratum, when first deposited, was the highest, until another was placed upon it; and so of all the others, until the deposition ceased.

457. *Fractured strata difficult to determine.*—When the strata, though once horizontal, have been broken, curved, or inclined, or perhaps placed the lower upon the upper, it is often difficult to decide concerning the original order of superposition. In these cases, which often occur to the experienced geologist, the only method of decision is to find, in the continuation of the strata, a spot where no disturbance has taken place, when the original order can be determined.

458. *Test of fossil remains.*—In cases where peculiar fossils, as a particular species of shells, are found in the seams of horizontal strata, and the same occur where the rock has been disturbed, and placed in an inclined, or even vertical position, the discovery of the same species in the disturbed strata, is a sufficient proof of a simultaneous deposition throughout the entire range. If, now, we descend a few yards, or sometimes even feet, below, or above, the strata, which might have been identified by these peculiar remains for hundreds of miles, we shall probably find an entirely different order of fossils, which identify another set of strata as before.

459. *Universal application of this test.*—The above test of the similar age of strata, by the identity of the fossil species they contain, has been verified in almost every part of the earth; and, says Mr. Lyell, has led to a conviction, that at successive periods of the past, the same area of land and water has been inhabited by species of animals and plants, as distinct as those which now inhabit the antipodes, or which now cöexist in the arctic, temperate, and tropical zones. It appears that, from the remotest period, there has been ever a new coming in of new organic forms, and an extinction of those which pre-existed on the earth; some species having endured for a longer, others for a shorter period; but none having ever rëappeared after they became extinct. This circumstance it is which confers on fossils their highest value as chronological tests, giving to each species, in the eye of the geologist,

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What is said of fossils as a test? How do fossil shells become the test of ages of rocks in different countries?

that authority which belongs to contemporary medals in history.

460. *Example of this test.*—As an example of the application of this test, suppose that the *terebratula*, an extinct species of shell, is found in England, France, and America, then it is concluded that the strata in which it occurs is of the same age, being formed at the same period, in all these countries. An experienced geologist, therefore, only requires a fossil shell in order to determine the comparative age, and perhaps the species of rock, to which it belonged, no matter how deep the strata, or distant the country where it was found.

461. *Test by included fragments.*—Sometimes the fragment of older rocks are included in the strata of the newer ones. This test may be of use where it is desired to decide the relative ages of formations, in the absence of more clear indications. Thus, in the neighborhood of a chalk formation, if clay-slate or sandstone contain nodules of flint, such as are found only in chalk beds, then it is evident that the chalk is older than the slate or sandstone, since it is by the disintegration of the former, that the latter has been able to afford such evidence.

RELATIVE AGES OF VOLCANIC ROCKS.

462. *Test by Superposition.*—If we find a volcanic product resting on an aqueous deposit, it is evidence that the volcanic matter is the newest of the two. But there may be cases where the reverse does not hold true; since, if we examine below the surface of an aqueous deposit, and there find a stratum of volcanic matter, it does not show that the latter is the oldest, and that the deposit has been formed on it, because the volcanic stratum might have been forced between the others, without reaching the surface. (See *Lign.* 91.)

463. *Test by the protrusion of dikes.*—When fused matter is forced up from below, forming dikes, (*Lign.* 80,) the strata on both sides are usually disturbed, showing clearly that these were formed before the disturbance, and therefore that the dike is the newest of the two.

464. *Test by included fragments.*—We may some-

Give an example of this test. How do included fragments become tests of the relative ages of rocks? Explain the test of age by superposition? How do dikes decide the relative ages?

times determine the comparative ages of volcanic rocks by the fragments of other rocks which they contain. Thus, if a stream of lava contains fragments of trap, we may know that the trap is the oldest. If rolled pebbles of trap are included in fossiliferous strata, it proves that the strata are the newest of the two. The reasons for both are obvious.

DIFFERENT AGES OF THE PLUTONIC ROCKS.

465. If we believe the Plutonic rocks, as granite, have originated at successive periods beneath the surface of the earth, we must be prepared to encounter greater difficulties in ascertaining their ages, than in the case of aqueous, or volcanic formations. Still the same general principles must here be employed as in the cases to which we have alluded.

466. *Test by relative position.*—Where fossiliferous strata are met with, reposing on granite, or other plutonic rocks, it must, of course, be inferred, that the inferiority of position is connected with the superior antiquity of the granite.

467. *Intrusion and alteration.*—But when granite, in the state of fusion, sends protrusive veins into gneiss, or other stratified rocks, as shown by *Lign.* 94, we must conclude that the gneiss is older than the intrusive matter.

468. *Test by mineral composition and appearance.*—In general, the proportions of the materials of which granite rocks are composed, as well as their colors, are remarkably uniform in the same ranges of mountains. But it is rare that these characters are the same in different ranges. An experienced mineralogist, by such differences, has no hesitation in pronouncing, at a glance, whether a hand specimen belonged to a certain range in the Alps, or in Scotland, or in particular parts of America. The sienite of Quincy, near Boston, is a good illustration of these differences; for although it has nothing remarkable in texture or color, yet the mineralogist, as well as the quarry-man, will distinguish it, in an instant, though mixed with hundreds of other granitic specimens. The geologist, from similar peculiarities of structure,

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Explain the test by included fragments. Explain the test of age by composition and appearance. Explain how granite, though the oldest of rocks, may be newer than gneiss.

or appearance, can often determine the original continuity of the same range, where portions of it have been disturbed, or covered over and buried by subsequent strata

469. *Rendered accessible only by upheaval and denudation.*—It is supposed, as already explained, that the granites, and other plutonic rocks, have originated at considerable depths under the land or sea, (364,) and therefore are never exposed to human observation until they are lifted to the surface by volcanic force, and afterwards laid bare by the action of water, or by denudation, (407.) We must, therefore, suppose that these rocks, in point of actual formation, are the most ancient materials of which the crust of the earth is composed. It may, however, be the case that they have been fused, and even taken their granitic structure, perhaps, in limited portions, long after the stratification of gneiss or mica-shist had commenced over them. In this case, as shown by *Lign.* 94, the fused granite must have been of more recent date than the superincumbent gneiss, though, in general, the great body of granite rocks had a priority of age.

DIFFERENT AGES OF THE METAMORPHIC ROCKS.

470. These rocks may be considered as having a two-fold age—one the period of their deposition, and the other the period of their crystaline change by igneous causes, (454.)

We can rarely hope, says Mr. Lyell, to define with exactness the date of both of these periods; the fossils having been destroyed by plutonic action, and the mineral characters being the same, whatever the age. Superposition itself is an ambiguous test, especially when we desire to determine the period of crystalization. Suppose, for example, we are convinced that certain metamorphic strata in the Alps, which are covered by cretaceous beds, are altered lias; this lias may have assumed its crystaline texture in the cretaceous, or some tertiary period—the Eocene, for example. If in the latter, it would be called Eocene, when regarded as a metamorphic rock, although it be liassic, when considered in reference to the era of its deposition. El. p. 294.

471. *Primitive limestone. Carara marble.*—We have

How do metamorphic rocks have a two-fold age?

already described a case, (448.) where limestone was changed by heat into metamorphic rock. It appears, from the following, that what is now Carara marble was once common limestone. This marble abounds in the Alps, and its great antiquity was inferred from its crystaline texture, from the absence of fossils, and from its passage into mica-shist, containing garnets. This marble, formerly supposed by geologists to have been formed before the existence of organic beings, has been proved to be altered limestone of the Oolitic period, and the underlying crystaline metamorphic rocks, are secondary sandstones and shales, modified by volcanic heat.

472. *Comparative ages of granite and metamorphic rocks.* —The undisturbed strata of the metamorphic rocks are superincumbent on granite, whenever both are found together. Hence the supposition that granite was the first created rock, having been called, by the old observers, the "backbone" of the earth. It was from the disintegration of this, and the transfer of its particles by water, that it was believed the stratified rocks, gneiss and mica-shist, were derived. Nor do modern facts appear to overthrow the foundation of this belief. When, therefore, gneiss and mica-shist are overlaying granite, and on the former we find fossiliferous strata, and over the strata, alluvium, and over the last, volcanic products, (all of which sometimes occur in the order named,) we are at no loss to decide, by the orders of superposition, which are the oldest, which middle-aged, and which the most recent of the series.

PART IV.

VOLCANOES AND EARTHQUAKES

CHAPTER XXXIV.

VOLCANOES;

THEIR GEOGRAPHY, GENERAL CHARACTER, AND GEOLOGICAL CONNECTIONS

473. THE effects of water, in changing the form of the earth's crust, by the deposition of strata and denudation, have been described in detail, to the extent of our limits. These effects are gradual, and generally so slow as to require centuries, in order to produce any considerable results. The changes produced by earthquakes, on the contrary, are often as sudden as they are calamitous and fearful; sometimes in a single hour, or even moment, not only reducing to fragments the most costly and solid monuments of man's industry, but also mutilating the face of the earth itself: tearing down mountains, elevating islands from the depths of the ocean, or burying whole countries under inundations of liquid fire.

GEOGRAPHY OF VOLCANOES.

474. It is a striking circumstance, in the history of volcanoes and earthquakes, that these awful exhibitions of nature have hitherto been almost entirely confined to certain regions of country. At present, the Andes of South America are among the best defined of these regions. Beginning with Chili, in the 46° of south latitude, and proceeding north to the 27° of the same latitude, we shall find a line of volcanoes so uninterrupted, that hardly a degree is passed without the occurrence of one of these agents in an active state. About twenty are enumerated within that space, and there is no doubt but many more exist, some of which are dormant, and perhaps some have become extinct. How long an interval of rest entitles a

volcano to be considered as extinct, is not determined. Those which have always been inactive since the era of history, may perhaps be so considered. The volcano of Ischia, in Italy, was silent for a term of 1700 years; after which, it again commenced a series of eruptions.

475. *Volcanoes of Chili.*—The volcanoes of Chili have their chimneys pierced through mountains of granite, thus exhibiting the effects of a degree of force, of which man, without the existence of such phenomena, could have no where gair ed the least conception. Villarcia is one of the principal volcanoes of this district. It is so elevated as to be visible at the distance of 150 miles, and burns without intermission. Every year the inhabitants of this province experience shocks of earthquakes. In 1822, the whole coast of Chili, to the extent of 100 miles, was elevated several feet by a subterranean convulsion, of which we shall give an account hereafter.

476. *Volcanic chains.*—Proceeding to the north, where the Andes attain their greatest elevation, we find in the province of Quito, Cotopaxi, Antisana, and Pichinca, all of them in an active state, and frequently emitting flames. Tunguragua, is also in the same district. This mountain, in 1797, threw out a deluge of mud, which filled valleys a thousand feet wide, and six hundred deep, forming barriers by which rivers were dammed up and lakes formed. North of Quito, in the provinces of Pasto and Popyan, occur six other volcanoes; and in the provinces of Guatamala and Nicaragua, which lie between the isthmus of Panama and Mexico, there are no less than twenty-three volcanic mountains, all of them situated between the 10° and 15° of north latitude, some of which are constantly in an active state.

This great volcanic chain, after being thus extended from south to north, nearly in a direct line, is continued through a great part of Mexico, from west to east. Here are five active volcanoes, known by the several names of Tuxtla, Orizaba, Popocatepetl, Jorullo and Colima. Still north of Mexico, in the peninsula of California, there are at least three, and, according to some, five burning mountains.

Thus we see that this volcanic chain extends nearly in an uninterrupted course from Chili to the north of Mexico, a distance of nearly 4,000 miles.

Another continuous volcanic range, of nearly equal

extent, begins at the Aleutian islands, belonging to Russian America, and by a circuitous route, passes to the Molucca islands. Through this whole extent, earthquakes of the most terrific description are common.

477. But our limits will not permit the enumeration of all the volcanic tracts described by authors. Besides those already mentioned, Kamschatka has seven burning mountains; the island of Java contains thirty-eight great volcanoes; the Molucca islands contain several, and among them that of Sumbawa, which, in 1815, suffered one of the most tremendous eruptions recorded in history. The islands of Jesso and Niphon, and Sumatra, contain more or less volcanoes; and from the Caspian sea to the Azores, is a volcanic range. Of Sicily and Italy it is hardly necessary to speak in this enumeration, since the descriptions of Etna and Vesuvius, or Herculaneum and Pompeii, are well known, and are sufficient to indicate the volcanic disposition of that part of Europe. The West India islands have occasionally suffered great calamities from this cause; and Iceland contains many burning mountains, among which is Skaptar Jokul, which, in 1783, suffered an extraordinary eruption, which we shall describe.

The whole number of volcanoes known is about 200.

478. *General characters and geological connections of volcanoes.*—The forms of volcanic mountains are generally so peculiar as to be distinguished from all others. They are commonly of considerable height, and sometimes very lofty. When solitary, they are of a conical form, and more or less truncated, that is, bearing the appearance of having been cut off at the top. When active, or but recently extinguished, the truncation has within it a cavity of greater or less size, called the *crater*.

The accurate form of a perfect crater is an inverted conoid, and on Cotopaxi and Teneriffe, they are surrounded by walls of lava, but most commonly this part is composed of ashes which have fallen down during eruptions. The size of the crater does not necessarily bear any proportion to that of the mountain. In some mountains, both the size and shape varies with every eruption.

479. *Proximity of volcanoes to the sea.*—In nearly all instances, volcanoes are seated near the sea, or in the vicinity of a large body of water, and it was formerly thought that proximity to the water, was absolutely

necessary to their action nor is it certain that this is not the case. The only exception to this general fact, is Jorullo, one of the burning mountains of the Andes, which is situated more than a hundred miles from the ocean, nor does it appear that any considerable body of water is near it. It has, however, been suggested, from some circumstances observed with respect to this mountain, that it may possibly communicate with the sea by a deep fissure.

In many instances, volcanoes have thrown out mud or water, instead of lava and ashes; and in some instances, fish of various kinds have been found in the water thus emitted, though no previous suspicion had existed of a communication between the mountain and the sea.

VOLCANIC ERUPTIONS.

480. The action of most volcanoes is periodical, or intermitting, though this is not the case with all. Vesuvius and Etna are sometimes dormant for a series of years; but Stromboli, in the vicinity of the former, has been constantly burning, ever since two hundred and ninety-two years before the Christian era, being upwards of two thousand years. Jorullo has continued to emit flames ever since 1759, at which time it was elevated from the plain on which it stands. But Vulcano suffered no eruption for eleven centuries, and we have already noticed that Ischia lay dormant for seventeen hundred years.

The appearances which attend volcanic eruptions, are various. In some instances, flames issue suddenly and silently from the cone, affording only splendid picturesque phenomena. But in others, the scene is the most terrific and appalling of which the imagination can conceive For these descriptions, we must, however, refer to particular eruptions, an account of which will follow.

The eruptions of Vesuvius and Etna, these mountains being in the midst of a highly cultivated people, are best described. Indeed, from the time of Pliny, to the present day, these have been the subjects of interesting and learned dissertations.

481. *First appearance of an eruption.*—In general, the first appearance of an eruption consists in a column of smoke, rising to a great height, and then spreading out in the form which Pliny compared to that of a pine tree.

This is followed by explosions from the crater; by trembling of the earth, or perhaps by its alternate rising and falling; the whole being attended by a rumbling, subterranean sound, forming both an eruption and an earthquake. Flame is then seen to issue from the cone, attended by red-hot stones, often thrown to the height of several hundred feet, producing, in the night, those brilliant and terrific phenomena, so often described. During the emission of the black smoke, and before the flame issues, there are often the most vivid flashes of lightning, which add greatly to the splendor of the scene. After these phenomena have existed for a longer or a shorter time, the melted lava, rising to the edge of the crater, flows over it, and runs down the side of the mountain into the plain below. This is in the form of a torrent of liquid fire, often narrow, but sometimes many miles in width. It sometimes proceeds rapidly, but more often slowly, the last portions of lava passing over the first, in small cascades. Sometimes, or from some mountains, there is much smoke, and but little lava; while from others, or at other times, the crater vomits rivers of melted matter, without smoke or flame.

The eruption of lava is often followed by showers of ashes, which consist of finely divided particles of lava, and which are often wafted by the wind to the distance of several hundred miles.

The quantity of matter ejected by some volcanoes, is astonishingly great. Brieslak, an Italian geologist, calculated that the quantity of lava which flowed from a volcano in the island of Bourbon, in 1796, amounted to 45,000,000 of cubic feet; and that the quantity from the same, in 1787, was 60,000,000 of cubic feet; and during one eruption from a mountain in Iceland, the lava flowed about ninety miles, having a width of at least twenty miles, and in some places, a depth of several hundred feet.

PARTICULAR ERUPTIONS.

We shall describe a few volcanic eruptions, selecting only those which have been the subject of peculiar, or scientific interest, or which have produced extraordinary effects, either with respect to the destruction they have caused, or the quantity of lava they have ejected.

482. *Eruptions of Vesuvius.*—The most ancient eruption of this Italian mountain, of which there is any par-

ticular description, was in A. D. 79, at which time the cities of Herculaneum and Pompeii were destroyed. It does not appear that any lava, or melted matter, was emitted at this eruption; the ejected substances being sand, ashes, and mud. But it is certain that this mountain had previously emitted lava, since the streets of this city are paved with this substance. The first stream of lava, of which there is any account, was in 1036, being the sixth or seventh eruption on record. From this period, all the eruptions which have taken place, are recorded, and many of them described by scientific men, and at great length.

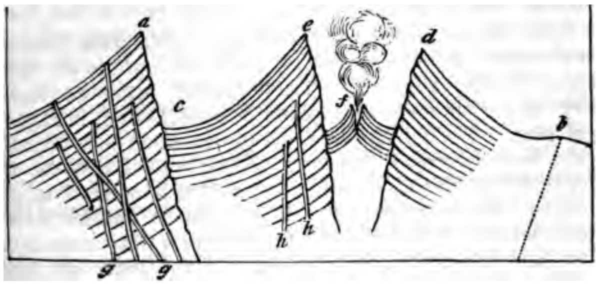
Some of them produced considerable changes, not only in the form and appearance of the mountain itself, but also of the country in the vicinity. That of 1538, elevated the land along the coast of Naples many feet, destroyed many villages, and produced Monte Nuovo, which is still 440 feet in height. A description and figure of this mountain has been given, *Lign.* 86.

The mountain reduced in height.—From about the end of the 18th century to 1822, the great crater of Vesuvius had been filling up gradually with lava, which boiled up from below, so that the bottom of the cavity presented a kind of rocky plain, covered with blocks, crags, and hillocks of volcanic matter. But during the latter year, in the month of October, the form and appearance of the ancient crater was entirely changed. The explosions at that time were so violent during twenty days, as to break up and throw out the whole of that accumulated mass, leaving an immense gulf, or chasm, about three miles in circumference, and in some parts 2,000 feet deep. At the same time about 800 feet in height, of the original cone or top of the ancient crater, was carried away by the explosions; so that Vesuvius became reduced in height, from about 4,200 to 3,400 feet.—*Forbes in Ed. Journal, and Scrope in Jour. of Science.*

483. *Regular strata in the crater.*—In ascending the mountain, its sloping sides are found to be covered with loose materials, intermixed with each other, without the slightest order, and just as they fell from the crater. But on arriving at the crater itself, the beholder is surprised to find that every thing is there arranged in the most perfect symmetry, and that the materials are disposed in regular undulating strata. These consist of alternate layers,

composed of lava, sand, ashes, and scoria, lying in distinct beds, and alternating with each other. These have resulted from the different colors and coarseness of these materials, and which severally remain in the same situation and succession as they fell from the air during the different eruptions.

LIGN. 100.



Eruption of Vesuvius.

In some parts of the crater, are seen dikes or veins, of more compact matter, intersecting the above-described strata. These are on the outside of the cone; and being harder than the volcanic matter through which they have passed, they have resisted decomposition, and therefore project above the surface.

These have undoubtedly been formed by the filling up of open fissures with liquid matter, forced up from below. At what period they were formed is unknown, but if such fissures are formed by the cooling, and consequent shrinking of the crater, after an eruption, it is probable that, at the next eruption, these are filled with the fused matter, so that some of these veins may be formed at every eruption.

484. *Veins and dikes in the crater.*—In the adjoining diagram, *Lign.* 100, from *Lyell's Geology*, these veins or dikes are represented, as also is the cone and crater of Vesuvius, and a part of the ancient Somma, as they appeared in 1828. *a*, Mount Somma, or the remains of the ancient cone of Vesuvius; *b*, the Pedamentina, a terrace-like projection, inclosing the base of the recent cone of Vesuvius on the south side; *c*, Atrio del Cavallo, so

called, because travelers leave their mules there, when they prepare to ascend to the cone on foot; *d e*, the crater of Vesuvius, left by the eruption of 1822; *f*, a small cone in the bottom of the crater, thrown up in 1828. In the bottoms of many craters there are several of these small cones, which are constantly emitting steam, or smoke, and sometimes throw up lava; *g g*, dikes intersecting the ancient strata of Somma; *h h*, dikes intersecting the recent cone of Vesuvius.

485. *Steam producing rain.*—Immense volumes of steam, or aqueous vapor, are evolved from the craters of volcanoes, during eruptions. These vapors, being condensed by the surrounding atmosphere, often fall down in torrents of rain. The rain precipitates the volcanic dust from the air, and sweeps that along which had fallen on the declivity of the mountain, until a torrent of mud is produced. Such torrents are as much to be dreaded as the inundations of mud which are sometimes thrown from the volcano; and, with the exception of the heat, are more disastrous than burning lava, being much more rapid in their descent. In 1822, one of these mud streams descended from Vesuvius, and, after destroying a district of cultivated ground, suddenly flowed into the villages of St. Sebastian and Massa, where, filling the streets, and some of the houses, it suffocated seven persons.

DESTRUCTION OF POMPEII AND HERCULANEUM

486. These cities were overwhelmed, and destroyed in the year A. D. 79, and most probably either by an alluvion of mud, such as we have just described, or by an emission of the same kind of matter from the mouth of the volcano.

It has been supposed, that it was by an eruption of lava that these cities were destroyed; but Lippi, an Italian writer, has shown that many facts presented by their ruins are incompatible with this opinion. Thus the casts, or impressions of persons, which still remain, especially of a woman, found in a vault at Pompeii, cannot be accounted for on the supposition of flowing melted lava, nor of falling volcanic ashes; for the first would have utterly destroyed the form of the body, and the second could not have reached through the roofs of the buildings.

487. *Not destroyed by lava.*—"There is decisive evi-

dence," says Mr. Lyell, "that no stream of lava ever reached Pompeii since it was first built, although the foundations of the town stand upon the old lava of Mount Somma, several streams of which have been cut through in making excavations. At Herculaneum, the case is different, although the substance which fills the interior of the houses and vaults, must have been introduced in a state of mud, like that found in similar situations in Pompeii; the superincumbent strata differ wholly in composition and thickness. Herculaneum was situated several miles nearer to the volcano, and has, therefore, been always more exposed to be covered, not only by showers of ashes, but by alluvions, and streams of lava. Accordingly, masses of both have accumulated on each other *above* the city, to a depth of no where less than 70, and in some places 112 feet. The tuff or mud, which envelops the buildings, consists of comminuted volcanic sand, mixed with pumice. A mask, imbedded in this matter, has left a cast, the small lines and angles of which are quite perfect, nor did the mask present the least indication of heat."

These cities were both sea-ports, and Herculaneum is still near the shore, but Pompeii is at some distance from it, the intervening land having been made, at various times, by volcanic matter.

Herculaneum was discovered 1713, by the accidental circumstance of a well being dug, which came directly upon the theatre, where the statues of Hercules and Cleopatra were found. These cities are mentioned by ancient authors, as being among the seven flourishing towns of Campania; they were originally settled by Greek colonies.

488. *Rebuilding of these cities.*—Both at Herculaneum and Pompeii, temples have been found, with inscriptions, commemorating the event of their rebuilding, after having been overthrown by an earthquake. This earthquake happened in the reign of Nero, sixty-three years after the Christian era, and sixteen years before the catastrophe by which they were finally destroyed.

It is supposed that about one-fourth of Pompeii is uncovered, presenting streets, walls, temples, houses, and monuments of art, many of them in the same condition as they were nearly 2000 years ago. Being covered with a deluge of mud, even the paintings have been preserved, and the wood remains in a perfect state. In some instances

the walls of the buildings are rent, probably by the earthquake which happened before the fatal eruption, but the edifices chiefly remain entire.

489. *Interesting ruins.*—Circumstances of great interest and curiosity are every where indicated among these ruins. Columns have been found lying upon the ground half finished, showing that the workmen were driven from their labors; and the temple, for which they were designed, remains unfinished. In some places, the pavement in the streets has sunk down; but, in general, it remains entire, consisting of great flags of lava, in which two immense ruts have been worn by the constant passage of wheel-carriages. When the hardness of the stone is considered, the continuity of these ruts, from one end of the town to the other, is not a little remarkable, for there is nothing like it in the oldest pavements of modern cities.

490. *Inhabitants mostly escaped.*—Only a very small number of skeletons have been found in either city; and it is therefore certain, that most of the inhabitants had time to escape, and also to take with them most of their valuable effects. In the barracks of Pompeii, were the skeletons of two soldiers, chained to the stocks; and in the vault of a house, in the suburbs, were the bones of seventeen persons, who appear to have fled there to escape the shower of ashes. They were found inclosed in indurated tuff or mud, which flowed from the mountain. In this was preserved the cast of a woman, perhaps the mistress of the house, with an infant in her arms. Though her form was impressed in the rock, nothing but her bones remained. To these bones a chain of gold was suspended around the neck, and rings with precious stones were found on the finger-bones of the skeleton.

The writings scribbled by the soldiers on the walls of the barracks are still visible; and the names of the owners, over the doors of their houses, are often easily read.

The colors of fresco paintings on the stuccoed walls, in the interior of the buildings, are frequently almost as vivid as if they were just finished. Some of the public fountains have their pavements decorated with shells, laid out in patterns, still retaining, in all respects, their original condition; and in the room of a painter, who was, perhaps, also a naturalist, was found a large collection of

shells, comprising a great variety of the Mediterranean species. These were in as good a state of preservation as if they had remained the same number of years in a museum.

Wood still sound.—The wooden beams of the houses at Herculaneum are black on the exterior, but when cleft open, they appear to be nearly in the state of ordinary wood, and the progress made by the whole mass towards the state of lignite, (mineralized wood,) is hardly appreciable. Even small substances, of vegetable origin, are often found in a state of entire preservation. Fishing-nets are abundant in both cities, and often quite perfect; and in a fruiterer's shop were found vessels full of almonds, chestnuts, and walnuts, all in perfect shape. And what is still more extraordinary, in a baker's shop was discovered bread, with the name of the maker stamped upon the loaf, thus: Eleris Q. Crani Riser. On the counter of an apothecary was a box of pills, converted into a fine earthy substance, and, by its side, a small cylindrical roll, evidently prepared to be cut into pills.

ERUPTIONS OF ETNA.

491. Etna appears to have been periodically active from the earliest times of history, for Diodorus Siculus mentions an eruption of it, which caused a district of country to be deserted by its inhabitants before the Trojan war; and Thucydides informs us that between the time when Sicily was colonized by the Greeks, and the commencement of the Peloponnesian war, that is, in 431 B. C., there had occurred three eruptions of this mountain.

Great eruption of 1669.—But, notwithstanding notices of this mountain were recorded thus early, the first eruption which has been particularly described, was the great one of 1669. An earthquake, previous to this eruption, had levelled many of the villages and towns in the neighborhood, and at the commencement of which, an extraordinary phenomenon happened in the plain of St. Lio. Here a fissure, six feet wide, and of an unknown depth, opened in the ground, with a loud, terrific, crashing noise, and ran in a tortuous course, nearly to the top of Etna. Its direction was from north to south, and its length twelve miles. This fissure, as it opened, emitted vivid flashes of light. Five other parallel fissures, of considerable length, after-

wards opened, one after the other, emitting smoke, and giving out the most horrid bellowings, which were heard to the distance of forty miles.

This case may, perhaps, explain the manner in which the dikes were formed in the cone of Vesuvius, already described and figured; for the light emitted by these fissures would seem to indicate, at least in some instances, that they were, to a certain height, filled with glowing lava.

492. *Fourteen towns destroyed.*—The lava, during this eruption, having overwhelmed and destroyed 14 towns, some of them containing three or four thousand inhabitants, at length arrived at the walls of Catania, a populous city, situated ten miles from the volcano. These walls had been raised sixty feet high, towards the mountain, in order to protect the city, in case of an eruption. But the burning flood accumulated against the wall, so as to fill all the space around and below that part, and finally poured over it in a fiery cataract, destroying every thing in that vicinity.

From Catania, the lava continued its course until it reached the sea, a distance of fifteen miles from its source, in a current about 1800 feet broad, and forty feet deep. While moving on, its surface was, in general, a mass of solid rock, or cooled lava, and it advanced by the protrusion of the melted matter, through this hardened crust.

As an illustration of the intense heat of volcanic matter, the Canon Recupero relates, that in 1766, he ascended a small hill, composed of ancient volcanic matter, in order to observe the slow and gradual manner in which a current of liquid fire advanced from Etna. This current was two and a half miles broad; and, while he stood observing it, two small threads of lava, issuing from a crevice, detached themselves from the main stream, and approached rapidly towards the eminence where he and his guide were standing. They had only just time to escape, when they saw the hill on which they had stood a few minutes before, and which was fifty feet high, entirely surrounded, and, in about fifteen minutes, entirely melted down into the burning mass, so as to be incorporated with, and move on along with it.

493. *Discovery of ice on Mount Etna.*—A remarkable discovery of a great mass of ice, on Mount Etna, was made in 1828. In that year, in consequence of the pro-

tracted heat of the season, supplies of ice at Catania and the adjoining parts of Sicily, failed entirely, and the people suffered considerably for the want of an article, considered as necessary to health, as well as comfort, in that hot climate.

In this dilemma, the magistrates of Catania directed search to be made for some crevice, or natural grotto, on Mount Etna, where drift-snow might possibly still be preserved. During this search, it was discovered that near the base of the highest cone, there lay a vast mass of ice, covered by a lava current. At what period this current was emitted is unknown; nor can it be conjectured what proportion of the ice was melted by the burning matter; but it appears that nothing but the flowing of the lava over this glacier, can account for its preservation.

A large number of workmen were immediately employed to quarry this ice for the use of the Catanians; but, it is said, that its hardness rendered the expense of obtaining it so great, that there is no probability of a similar undertaking, unless under similar circumstances.

VOLCANOES IN ICELAND.

494. Iceland is both a volcanic country, and a country of volcanoes. A considerable proportion of its surface is covered with ancient or modern lava, and it is now subject to the most dreadful calamities from this source.

With the exception of Etna and Vesuvius, the most complete chronological records of volcanic eruptions are those of Iceland. From these it is ascertained, that from the twelfth century, there has never been an interval of more than forty years, and rarely more than twenty, without eruptions and earthquakes in some part of that country. Single eruptions of Mount Hecla, have sometimes continued for six years. In many instances, the whole island has been convulsed by earthquakes, during which mountains were rent asunder, hills sunk down, and rivers have deserted their former channels.

ERUPTION OF SKAPTAR JOKUL.

495. In 1783, this volcanic mountain suffered one of the most extraordinary eruptions recorded in history, both with

respect to the quantity of lava it threw out, and the calamities it occasioned.

The river Skapta, a considerable stream, was for a time completely dried, by a torrent of liquid fire from this mountain. This river was about two hundred feet broad, and its banks from four to six hundred above the level of the water. This defile was not only entirely filled to a considerable extent by the lava, but it also crossed the river by the dam thus formed, and overflowed the country beyond, where it filled a lake of considerable extent, and great depth.

This eruption commenced on the 11th of June, and on the 18th of the same month, a still greater quantity of lava rushed from the mouth of the volcano, and flowed with amazing rapidity, sometimes over the first stream, but generally in a new course. The melted matter having crossed some of the tributary streams of the Skapta, completely dammed up their waters, and caused great destruction of property and lives, by their overflow. The lava, after flowing for several days, was precipitated down a tremendous cataract, called Stapafoss, where it filled a profound abyss, whioh that great water-fall had been excavating for ages, and thence the fiery flood continued its course.

On the 3d of August, a new eruption poured forth fresh floods of lava, which, taking a different direction from the others, filled the bed of another river, by which a large lake was formed, and much property and many lives destroyed.

The effects of this dreadful calamity may in some measure be imagined, when it is known, that although Iceland did not, at that time contain more than 50,000 inhabitants, there perished 9,000 human beings by this single eruption, making nearly one in five of the whole population. Part of them were destroyed by the burning lava itself; some by drowning, others by noxious vapors which the lava emitted, and others in consequence of the famine, caused by the showers of ashes, which covered a great proportion of the island, and destroyed the vegetation. The fish also, on which the inhabitants depended, in a great measure, for food, entirely deserted the coast.

Quantity of lava.—The quantity of lava which Skaptar Jokul emitted during this eruption, was greater than is recorded of any other volcano. The two principal branches,

or streams of lava, flowed chiefly in different directions. The length of the smallest was forty miles, and of the other fifty miles. The breadth of that branch which filled the Skapta, was from twelve to fifteen miles, and the other about seven miles. The ordinary depth of each was about 100 feet; but in narrow defiles, it was more than 600 feet deep, and in many places, from 200 to 300.

Allowing that the united breadth of this vast lava stream was 20 miles, and the whole length 90 miles, then this mountain, at a single eruption, threw out a quantity of lava which covered a surface of 1,800 square miles, an area equal to the fourth part of the State of Connecticut, and nearly one-half the size of Rhode Island.

When it is considered that the depth of the whole might average 150 feet, we may go into calculations concerning the quantity of matter thrown out; but we can have no conception of the force required to elevate such a stream of melted rock through the crust of the earth.

ERUPTION OF JORULLO, IN 1759.

496. Jorullo is situated in the interior of Mexico, about 100 miles from the nearest sea. This mountain, as already stated, affords the only known instance of a volcano, at a distance from some ocean. It also affords an instance of the production of a new volcanic mountain, within the memory of man.

In June, 1759, subterranean sounds of an alarming kind were heard by the inhabitants of this district, and these were followed by earthquakes, which succeeded each other for two months. In the month of September, flames were seen to issue from fissures in the ground, and from the same place, red-hot rocks were thrown to an immense height. Soon after, six volcanic cones were formed of lava and the fragments of rock, thrown up from the earth, in the same neighborhood. The least of these was three hundred feet in height. In the midst of these cones, rose Jorullo, which was formed in the same manner, and soon rose to the height of 1,600 feet by the accumulation of lava and fragments of rock. The small cones ceasing their action, Jorullo became the great outlet of volcanic matter, and continued to emit lava and large fragments of primitive rock, for many months. Jorullo has continued to emit flames ever since its formation.

VOLCANO OF SUMBAWA.

497 Sumbawa is one of the Molucca islands; and the mountain from which occurred, on some accounts, the most extraordinary volcanic eruption of which any accounts have been recorded, is called Tomboro.

This eruption commenced on the 5th of April, 1815, but was most terrific on the 11th and 12th of that month; nor did it cease entirely, until some time in the following July. The explosions so much resembled the firing of heavy cannon at a distance, that the people of many vessels at sea, supposed there was a great naval engagement within hearing, but could not imagine what nations were engaged.

Explosions heard 900 miles.—The commanders of some ships, and of several English forts, gave orders to prepare for battle, though they were several hundred miles distant from the mountain. At Sumatra, these tremendous explosions were distinctly heard, though not nearer than 900 miles from Tomboro. They were also heard at Ternate, in the opposite direction from Sumatra, at the distance of 720 miles from the mountain.

So immense in quantity was the fall of ashes, that at Bima, forty miles from the mountain, the roof of the English Resident's house was crushed by the weight, and many other houses in the same town were rendered uninhabitable from the same cause. At Java, 300 miles distant, the air was so full of ashes, that from this cause at mid-day, it is said the darkness was so profound, that nothing like it had ever before been experienced, during the most stormy night.

Terrible effects of this eruption.—Along the coast of Sumbawa, the sea was covered with floating lava, intermixed with trees and timber, so that it was difficult for vessels to sail through the mass. Some captains, though at a long distance at sea, mistook this mass for land, and sent out their boats in order to ascertain the safety of their situations. The sea, on this and the neighboring coasts, rose suddenly to the height of twelve feet, in the form of immense waves, and as they retired, swept away trees, timber, and houses, with their inhabitants. All the vessels lying near the shore were torn from their anchorings, and cast upon the land. Violent whirlwinds carried into

the air, men, horses, cattle, trees, and whatever else was in the vicinity of the mountain. Large trees were torn up by the roots, and carried into the sea. But the most calamitous part of the account still remains: for such were the tremendous effects of the burning lava; the overflowing of the sea; the fall of houses; and the violence of the whirlwind, that out of 12,000 inhabitants on this island, only 26 individuals escaped with their lives, all the rest being destroyed in one way or another.

The whole island was completely covered with ashes, or other volcanic matter. In some places, the bottom of the sea was so elevated as to make shoals where there was deep water before; and in others, the land sunk down, and was overflown by the sea.

The details of this awful calamity were collected, and published by Sir Stamford Raffles, then Governor of Java, who required all the residents in the various districts under his authority, to send him a statement of the circumstances which fell under their several observations.

EARTHQUAKES.

Having thus given a short history of a sufficient number of volcanic eruptions, to acquaint the geological student with the phenomena, and of the tremendous, as well as calamitous effects of these mighty agents, we will next refer to the subject of earthquakes, as resulting from the same cause.

EARTHQUAKE OF CALABRIA.

498. " Of the numerous earthquakes," says Mr. Lyell, "which have occurred in different parts of the globe, during the last 100 years, that of Calabria, in 1783, is the only one of which the geologist can be said to have such a circumstantial account, as to enable him fully to appreciate the changes which this cause is capable of producing in the lapse of ages. The shocks began in February, 1783, and lasted nearly four years, to the end of 1786." The importance of the earthquake in question, arises from the circumstance, that Calabria is the only spot hitherto visited, both during and after the convulsions, by men possessing sufficient leisure, zeal, and scientific information, to enable them to collect and describe with accu-

racy, the physical facts which throw light on geological questions.

Authors who witnessed the phenomena of these convulsions, are quite numerous. Among them, it is said that Pignataro, a physician, who resided at the centre of the earthquakes, and who kept a register of the number and force of the shocks, is among the most correct. The Royal Academy of Naples, also sent a commission from their own body to Calabria, accompanied by artists, with instructions to describe, and illustrate by drawings, the effects of these terrible convulsions; and Sir William Hamilton, who surveyed this district before the shocks had ceased, has added many facts, not recorded by others. Our limits will, however, allow only a very brief summary of the facts from these several sources.

The subterranean concussions were felt beyond the confines of Sicily; but if the city of Oppido, in Calabria, be taken as the centre, a circle around it, whose radius is twenty-two miles, would include the space which suffered the greatest calamities. Within this circle, all the towns and villages were almost entirely destroyed.

The first shock, which took place on the 5th of February, 1783, threw down, in the space of two minutes, a greater part of the houses, within the whole space above described. The convulsive motion of the earth is said to have resembled the rolling of the sea, and that, in many instances, it produced swimming of the head, like seasickness. This rolling of the surface, like the billows of the sea, was like that which would have been produced by the agitation of a vast mass of liquid matter under the ground.

In some walls which were shattered, the separate stones were parted from the mortar, so as to leave an exact mold where they had rested, as though the stone had been carefully raised from its bed in a perpendicular direction; but in other instances, the mortar was ground to powder between the stones, as though they had been made to revolve on each other.

It was found that the swelling, or wave-like motions, and those which were called *vorticose*, or whirling, often produced the most singular and unaccountable effects. Thus, in some streets, in the town of Monteleone, every house was thrown down, except one, and in some other

streets, all except two or three; and these were left uninjured, though differing in no respects from the others.

In many cities all the most solid edifices were prostrated, while those which were slightly built escaped; but, in others, it was precisely the reverse, the massive buildings being the only ones that remained standing.

LIGN. 101.

Obelisks of St. Bruno.

499. *Singular effects of volcanic action.*—But, perhaps, the most singular effect was that produced on a pair of obelisks, at the convent of St. Bruno, where the different stones composing these monuments, were moved on each other, in a manner altogether unaccountable, unless, indeed, it can be supposed that the earth, where each stood, underwent a rapid gyratory motion. The shock which shook the convent, is said to have been of that kind which writers describe by the term vorticose, or whirling. The annexed cut, *Lign.* 101, will convey an idea of these effects.

The pedestal of each obelisk remained in its original situation and place; but the separate stones were turned partly around on each other, as represented in the figures; some of them being moved eight or nine inches out of their places, but none were thrown down.

500. *Upward motion of the earth.*—It appears, from the statements, that in many instances, where the ground was

fissured, the motion must have been from below, upwards; for these fissures opened and closed alternately, as though the ground, in that particular spot, had been violently lifted up with a force from below, by which a fissure was formed; but, the force ceasing instantly, the ground again assumed its former position, and the fissure closed. Perhaps the escape of some gas or steam through the fissure, produced this effect.

In many instances, these fissures were so wide, as in an instant to swallow up men, trees, and even houses; and when the earth sunk down again, it closed upon them so entirely, as not to leave the least vestige of what had happened, nor were any signs of them ever discovered afterwards. In the vicinity of Oppido, the centre of these convulsions, many houses were precipitated into the same great fissure, which immediatly closed over them; and, in the same neighborhood, four farm-houses, several oil-stores and dwelling-houses were so entirely ingulfed, that not a vestige of them was seen afterwards.

In some instances, these chasms did not close. In one district, a ravine, formed in this manner, a mile long, 100 feet broad, and 30 feet deep, remained open; and in another, a similar one remained, three-quarters of a mile long, 150 feet wide, and 100 feet deep; in another instance, there remained such a chasm, 30 feet wide and 225 feet deep.

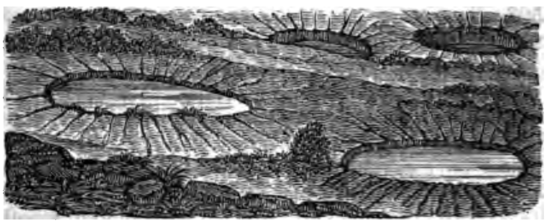
501. *Springs formed.*—In various places, the ground sunk down, and lakes were formed, which, being fed by springs, have remained ever since. The convulsions also removed immense masses of earth from the sides of steep hills into the valleys below; so that, in many instances, oaks, olive orchards, vineyards, and cultivated fields, were seen growing at the bottoms of deep hollows, having been removed from the side hills of the vicinity. In one instance, a mass of earth, 200 feet thick and 400-feet in diameter, being set in motion by one of the first shocks, traveled four miles into the valley below.

The violence of the upward motion of the ground was singularly illustrated by the inversion of heavy bodies lying on the surface, and which can hardly be accounted for, except on the supposition that they were actually thrown to a considerable distance into the air. Thus, in some towns, a considerable proportion of the flat paving-

stones were found with their lower sides uppermost. Mr. Lyell accounts for this effect, by supposing that the "stones were propelled upwards by the momentum which they had acquired. and that the adhesion of one end of the mass being greater than the other, a rotary motion had been communicated to them." But it is difficult to conceive how a whirling motion, so rapid as to produce such an effect, could have been communicated to a whole town, without producing some consequences still more extraordinary.

502. *Singular fissures.*—In the plain of Rosarno, a different effect was produced from any yet described. This plain consists of an alluvial soil, which, after the commencement of the earthquakes, was found covered with circular hollows, containing water, and around the hollows were fissures, radiating from their sides in every direction, as represented by *Lign.* 102.

LIGN. 102.

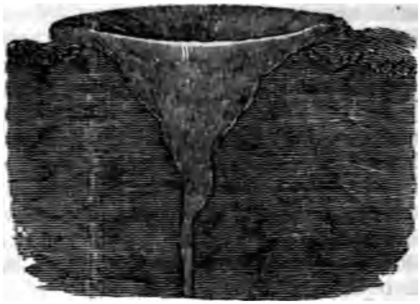


Radiated fissures.

These were, for the most part, about the size of carriage-wheels, but sometimes larger or smaller. When filled with water to within a foot or two of the surface, they appeared like wells; but more commonly they were filled with dry sand, sometimes with a concave, and at others with a convex surface. On digging into the earth, these cavities were found to be funnel-shaped, the moist loose earth in the centre, indicating the tube through which the water had ascended. The annexed cut, *Lign.* 103, is intended to represent a section of these inverted cones. when the water had disappeared, leaving nothing in it but dry micaceous sand. This sand appeared to have been brought up from beneath by the water, which was sometimes found over the sand.

But our limits will not allow the description of other effects and appearances, which this dreadful calamity produced, some of which are equally curious and inexplicable.

LIGN. 103.



Tunnel-shaped cavity.

503. *Destruction of Prince Scilla and his people.*—We must not, however, close this account without reference to an incident connected with the destruction of human life, as well as to the number of responsible beings which were suddenly called to the world of spirits, by this appalling act of a mysterious Providence.

The Prince Scilla had persuaded many of his people to betake themselves to their fishing-boats, as a place of safety, on the first indications of an earthquake, which in that volcanic country are so well understood, and which creates so much alarm. The prince himself had set the example, by going on board of one of these boats. On the fifth of February, when the first violent shock happened, many of these people were sleeping in their boats near the shore, while others were on the shore, at a place little elevated above the sea. With this convulsion the earth rocked, and suddenly there was precipitated a great mass of rock from Mount Jaci, on the plain where the people had taken refuge; and immediately after, the water rose to a great height above its ordinary level, and swept away the sleeping multitude. The wave then instantly retreated, but soon after returned again with increased violence, bringing back many of the people, and animals, which it had carried away. At the same time every boat in the

vicinity was overwhelmed, or dashed against the beach, and thus destroyed. The prince, who was an aged man, with 1,400 of his people, were thus swept away, and perished in the sea.

The number of human beings who were destroyed by this series of earthquakes, was estimated by Sir William Hamilton, at about 40,000; besides which, nearly 20,000 more died by epidemics, which were occasioned by insufficient nourishment, and the noxious vapors arising from the new lakes and pools of water, which this terrible catastrophe occasioned,—thus making the whole number that perished 60,000.

504. *Earthquakes cease when the eruption commences.*—In countries where volcanoes exist, and which are also subject to earthquakes, experience has taught, that the earthquakes cease, or become harmless, so soon as an eruption from the mountain commences. On the supposition that the earth constantly contains within it an ocean of lava or melted matter; that earthquakes are caused by some disturbance of this liquid; and that volcanoes are its chimneys, or outlets when thus disturbed, this fact would admit of an easy explanation. In another place, we shall bring forward many circumstances, to show that this theory may be true; and shall only remark here, that the Calabrian earthquakes may be brought as an item in support of this doctrine; for neither Etna nor any of the Italian volcanoes, suffered the least sign of eruption during these destructive convulsions.

EARTHQUAKE OF LISBON.

505. This great earthquake happened in the month of November, 1755, and, with respect to the wide extent to which it was felt, exceeded all others of which there is any account.

The first intimation of its approach was a loud subterranean noise, somewhat like distant thunder, and immediately afterwards, the city of Lisbon was shook with such violence as to prostrate nearly all its houses. The wretched inhabitants, with so short a warning, were unable to take the least precaution for their safety, so that in about six minutes 60,000 people perished.

The sea at first retired, and laid bare the bed of the harbor, after which it immediately rolled back, in an immense

wave, rising fifty feet, at least, above its ordinary level. The largest mountains in Portugal were shaken to their foundations, and several had their summits rent in a manner which struck every beholder with astonishment.

506. *Sinking of the quay.*—But the most extraordinary and calamitous effect which was produced at Lisbon, was the sinking of the quay, together with the thousands of inhabitants with which it was covered. This work was built entirely of marble, and just finished at an immense expense; and on it, after the first shock, a vast concourse of people had collected as a place of safety, having left the city to escape the fall of the houses. But it proved the most fatal spot in the vicinity; for at the next shock the earth opened and instantly swallowed up the whole quay, with the multitude which had there assembled; and so completely were the whole retained by the closing of the earth, that not a single dead body ever rose again to the surface. A great number of small boats and other vessels, near the quay, filled with people, as a place of safety, were also precipitated into the yawning vortex; and it is stated that not a single fragment of any of these boats was ever seen afterwards. It was believed that the water where the quay stood was unfathomable, but its depth was afterwards found to be 600 feet.

507. *Extent to which it was felt.*—The immense area over which this earthquake was felt, is very remarkable; for not only was every part of Spain and Portugal convulsed, but the shocks were perceived, with greater or less intensity, in England, Holland, Italy, Norway, Sweden, Germany, Switzerland, Corsica, the West Indies, at Morocco and Algiers in Africa, and in a part of South America. At Algiers the shock was so violent as to throw down many buildings; and a village, not far from Morocco, was swallowed up, and 10,000 inhabitants perished. A great wave from the sea swept nearly the whole coast of Spain. At Cadiz its height is said to have been sixty feet, and its devastations in proportion.

508. *Shocks felt at sea.*—The shock was also felt by ships far at sea, and, in several instances, the concussion was such as to make the people suppose their vessels had struck on a rock. In one instance, it is said that the people on board a vessel off the West Indies, were thrown up a foot and a half from the deck. This circumstance may

be accounted for from the inelasticity of water; so that a violent and sudden movement of the bottom of the ocean, would be communicated to the surface and to the ship, through the medium of the fluid, with nearly the same force as though the vessel had been on the ground itself.

ISLANDS RAISED FROM THE SEA.

509. Numerous instances are recorded of the elevation of islands, of greater or less extent, from the bottom of the sea.

Writers of antiquity have mentioned several such instances. The elder Pliny says that the celebrated islands of Rhodes and Delos, according to tradition, are sea-born, and that, after these, several smaller islands rose up from the bottom of the same sea. Strabo also asserts positively, that Hiero was produced in the midst of flames; and both Plutarch and Justin relate, that the formation of this island was attended with much fire, and a great boiling of the sea.

But we are not entirely dependent on the ancients for facts of this kind, many instances of the elevation of islands having been witnessed in later times.

Captain Tillard, of the Royal British Navy, was an eye-witness to the rising of an island from the ocean, in 1812.

At some distance off the coast of St. Michael's, one of the Azores, an immense body of smoke was observed to issue from the water, and from the midst of the smoke, there suddenly burst forth a black column of cinders, ashes and stones, in the form of a spire. This was accompanied by vivid flashes of lightning from the thickest part of the volcanic smoke, and the whole was surrounded by occasional water-spouts.

The water at this place was thirty fathoms deep, and after the volcanic phenomena had lasted four days, the crater began to appear above the surface of the water, and soon became twenty feet high in the midst of an island 400 feet in diameter. At this time the cliffs of St. Michael's were shattered by an earthquake, and the island continued to rise until it became at least 200 feet above the level of the sea.

This island was named Sabrina, after Captain Tillard's ship. It did not, however, long continue visible; for being formed chiefly of ashes and cinders, and not by the eleva-

tion of the solid rocks, it was soon swept away by the waves of the ocean.

510. *Aleutian islands.*—In the year 1806, there arose from the sea a new island, among the Aleutian group, north of Kamschatka. This, according to Langsdorf, who afterwards visited the spot, was four geographical miles in circumference; and the geologist, Von Bush, infers, from its not having subsided, that it does not, like Sabrina, consist of ejected volcanic matter, but of solid rock, thrown up from the bottom of the sea.

In 1814, another island was added to the Aleutian group, from the bottom of the sea. This was much larger than the former, and its highest part was elevated to the astonishing height of 3,000 feet above the level of the sea.

In 1820, a new island was thrown up among the Ionian group, on the coast of Greece.

In 1757, eighteen small islands were elevated from the sea, in the vicinity of the Azores.

In 1783, the same phenomenon happened on the coast of Iceland.

Many other instances of sea-born islands are recorded; but we need not extend this list, our chief object being to show that islands are elevated from the ocean by the force of volcanic action.

511. *Elevation of land by volcanic power.*—In November, 1822, there happened a series of subterranean convulsions on the coast of Chili, which continued three months, and which shook that part of South America to the extent of 1,400 miles from north to south. On the morning after the first shock, the whole line of coast along Valparaiso, to the distance of 100 miles, was found to have been raised above its former level. Mrs. Graham, who was present, and who writes this account, states that on the morning of the 20th, the wreck of an old ship, which lay at a small distance from the shore, but which could not be approached, on account of the depth of the water, was now easily accessible. She also found the former bed of the sea, along the shore, laid bare, with muscles, oysters, and other shell-fish, adhering to the rocks on which they grew, and abundance of fish, dead and on dry land. At Valparaiso, the elevation of the land was found to be three feet; but at other places the rise was from four to five feet.

TEMPLE OF JUPITER SERAPIS.

512. In a few instances, it is known that portions of land have several times changed their level, with respect to that of the sea; and of which the following is an interesting and curious example.

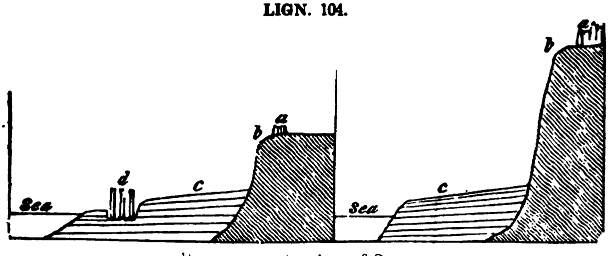
The temple of Serapis, a celebrated monument of antiquity, is situated on the little bay, called Baiæ, within the bay of Naples.

A geological examination of the coast of Puzzuoli, along this bay, shows that this land has been elevated about twenty feet, at a period not very remote; so that, without the evidence presented by the temple, there is sufficient proof that the land in the vicinity has changed its level.

If the coast along the shore, between Naples and Puzzuoli, be examined, it will be seen that the tract of fertile land which intervenes between the present shore and the high rocky cliffs, was evidently once under the water, and that the ancient shore was near these cliffs.

The inland cliff near Puzzuoli, is in many places about eighty feet high, and quite perpendicular. At its base, the new deposit attains the height of twenty feet above the sea. This consists of sedimentary matter, mixed with marine shells, showing that it was formed under the water.

LIGN. 104.



Puzzuoli and ruins of Serapis.

The annexed *Lign.* from Mr. Lyell, will explain the situation of this coast in 1828. *a*, on the right, shows the situation of antiquities, on a hill south of Puzzuoli; *b*,

ancient cliff, now inland; *c*, terrace, composed of marine deposits of recent date; *a*, on the left, represents the remains of Cicero's villa, at the north of Puzzuoli; *b*, ancient cliff, now inland; *c*, terrace, composed of recent marine deposits; *d*, temple of Serapis.

The soil of these level deposits is considered so valuable, that a wall has been built for its protection against the washing of the sea; but, in some places, the wall has been thrown down, so that the strata are exposed. These consist of alternate layers of mud and pumice, inclosing abundance of marine shells. One stratum contains large quantities of the remains of ancient art, as tiles, and pieces of Mosaic pavement.

(Ancient Mosaic pavement consists of small pieces of stone, generally marble, of different colors, arranged in figures, sometimes representing groups of men and animals, in commemoration of some historical event. These are cemented so as to form a continuous solid mass. The floors of ancient churches and temples were often thus made.)

The remains of the works of art are found below, as well as above, the marine shells. Among the shells are the Cardium, Donax, Buccinum, and Ostrea.

513. *No tides in the Mediterranean.*—Now, there are no tides in the Mediterranean, by which these shells could have been cast upon the shore; and the remains of ancient buildings, at other places, show that there has been no change in the level of this sea, for the last two thousand years; hence, we must conclude, that the land along this coast has been elevated about twenty feet above its former level.

But, in addition to the above evidence, the remains of the temple of Serapis show that the edifice has undergone several changes of level, when compared with the sea.

With respect to this temple, Mr. Lyell, who has lately visited the spot, says: "It appears, from the most authentic accounts, that the three pillars, now standing erect, continued, down to the middle of the last century, half buried in the new marine strata above described. The upper parts of the columns, being concealed by bushes, had not been discovered, until 1750, when they were seen to form part of a splendid edifice. On examination, the

pavement was found still entire, and upon it lay a number of magnificent columns, a part of which were of African breccia, and a part of granite. (Breccia is a rock composed of broken, angular pieces of stone, generally of various colors, cemented by the hand of nature. The pillars of the capitol, at Washington, are of this kind of marble.) The original plan of the building could be traced distinctly: it was of a quadrangular form, seventy feet in diameter, and the roof had been supported by forty-six noble columns, twenty-four of which were of granite, and the rest of brecciated marble. The large court had been surrounded by apartments, supposed to have been used as bathing-rooms; for a thermal spring, still employed for medicinal purposes, continues to flow from just behind the ruins, and the water of this spring, it is said, was conveyed to the chambers by marble conductors."

LIGN. 105.

Temple of Serapis.

514. *Temple of Serapis, a bathing-house.*—Since the discovery of these remains, many antiquaries have entered into elaborate discussions, on the question to what deity this edifice was consecrated; but from its situation and construction, there is more reason to suppose that it was a bathing-house, than a heathen temple.

But our object will be to show what geological changes these antiquities indicate.

The annexed cut *Lign.* 105, represents Serapis, as it

now appears, reduced from the drawing of Mr. Lyell. These pillars are forty-two feet in height, and their surfaces are smooth and entire, to the height of about twelve feet above the pedestal, the reason of which will appear directly. Above this is a zone, twelve feet in length, where the marble has been pierced by a marine perforating shell-fish, called by Cuvier, Lithodomus. It is a species of the Mytilus of Linnæus and the Modiola of Lamarck.

515. *Habits of the Lithodomi.*—These animals enter the stone by a small orifice, which they make themselves when quite young, and as they increase in size, they enlarge their habitations in proportion. They are nourished by the sea-water, which is admitted through the small aperture. These animals have not the power, or perhaps inclination, to leave their cells; hence, their houses, during life, become their tombs at death.

The limestones, on the shores of the Mediterranean, are frequently full of the excavations of these animals. The genus Pholas, also contains some species which penetrate rocks. Both are figured under the articles "Multivalves" and "Bivalves." (*See pages* 110—111.) These animals cannot pierce silicious rocks, such as granite.

As these animals cannot live, except when immersed in salt water, we must infer that these pillars were for a long time submerged, and that, during part of that period, their lower portions were covered up by the rubbish already mentioned, while their upper ends reached above the water. This accounts for the reason why their middle portions only are perforated by these animals. On the pavement of the temple lie several columns, broken in pieces. These are perforated on their fractured ends, as well as on other parts, showing that they had lain under water for a long time after they were broken.

The platform of the temple is at present just under the water, and the upper part of the perforations on the standing columns is at least twenty-three feet above the water, from which it is clear that these columns must have continued for a long time immersed in the water, while in an erect position; after which, they must have been raised, by the rising of the ground, to their present elevation.

516. *Elevation and depression of Serapis.*—Thus it appears that the temple of Serapis was first depressed by

the sinking down of the ground where it stands, so that the water of the sea surrounded these pillars about twenty feet above its present level; after which, it was again raised to its present situation, by the elevation of the coast. It is hardly necessary to say, that the cause of these changes, was undoubtedly the same which has produced the elevation of islands, and the sinking down of the ground in other places.

SEAT AND THEORY OF VOLCANOES.

517. It was formerly believed that the seat of volcanoes was superficial, and that the heat which fused the rocks, and sent them forth in the form of lava from the mouths of volcanoes, was owing to the combustion of mineral coal. It is a sufficient refutation of this hypothesis, that were the whole interior of the earth composed of coal, it must have long since been exhausted in the vicinity of ancient burning mountains. Also, that no geologist ever supposed coal to exist below granite mountains, which are often pierced by volcanic apertures.

518. *Supposed ignition of pyrites.*—The cause of volcanoes has also been attributed to the spontaneous ignition of pyrites, or metallic sulphurets.

With respect to this theory, in the first place, there is no evidence that the interior of the earth is composed of the sulphurets of the metals; nor is this in the least degree probable; and, second, were this ascertained to be the case, and could the theorist contrive to perpetuate its ignition, or to make it occasional, as circumstances required, still, it would fail to account for the phenomena of earthquakes and volcanoes. But, lastly, the products of volcanoes are not such as would result from the ignition of the sulphurets of the metal. This is sufficient.

519. *Attributed to the metallic oxyds.*—Since the great discovery of Sir H. Davy, that the earths and alkalies are the oxyds of metallic substances, it has been proposed to account for volcanoes and earthquakes, by the admission of water to these metallic elements.

This theory may be thus stated: If pure potash or soda be deprived of its oxygen, there remains a brilliant silver-white metal, so light as to swim on the surface of water.

These metals have an affinity of oxygen so strong, that when thrown on water, the fluid is decomposed, the oxy-

gen being absorbed by the metal so rapidly as to occasion a degree of heat, which sets the hydrogen on fire. Thus, by throwing these metals on water, combustion is excited, and the oxyds of potassium, and sodium, or in other words, pure potash or soda, is formed.

Now, if we suppose that, at the creation, the elements of things were formed in a distinct and separate state, and that the condition of the earth's surface at the present time is owing to the exercise of chemical affinities, then we might consider the interior of the earth, at the present time, to be composed of elements in their simple and uncombined state. This being admitted, the earth, at a certain depth, consists of the bases of these earths and alkalies, in their uncombined and metallic forms; for, being excluded from any substance containing oxygen, there has been no opportunity, since the creation, for these substances to combine, and form compounds. It is well known to chemists, that the metallic bases of the alkalies may be kept in their elementary state for any length of time, by excluding them from the air, or by immersing them in naphtha, a substance containing no oxygen. Hence, as combustion is excited, when these metallic bases come in contact with water, (if the above suppositions be true,) there exists an analogy, by which it has been thought the phenomena of earthquakes might be accounted for, by the admission of water to these substances.

520. *Objections to this hypothesis.*—There are, however, insuperable difficulties in this hypothesis. Carbonate of lime is one of the most abundant materials of which the crust of our earth is composed. This, in the opinions of many geologists, had its origin in organized remains, being the product of sea-shells, consolidated in a manner, which it is unnecessary here to explain. It is quite certain that a great portion of limestone is really the product of moluscous animals, of which the coral reefs, and the mountains of shells, are a sufficient proof. If, therefore, lime is the product of organized beings, it was not created in an elementary form, and therefore cannot produce the fire of volcanoes by the union of its elements, though *calcium*, its base, may excite flame by contact with water.

Silex, or flint, another substance which enters largely into the composition of the earth, and of which the primi-

tive rocks are chiefly composed, does not possess an inflammable base, and therefore cannot be supposed to participate in causing any igneous phenomena.

The specific gravity of the earth, also, being at least five times that of water, shows that it is not composed, principally, of substances lighter than that fluid.

Besides, the phenomena of earthquakes and volcanoes, even admitting the interior of the earth to be composed of metallic elements, are not such as could be accounted for by the admission of water to these substances; nor are the products of volcanic action, in the form of lava, pumice, and ashes, such as would result from the oxygenation of metallic elements. This theory, therefore, has not even plausibility in its favor.

521. *Central fire the most probable cause.*—In the present state of geological knowledge, it is not to be expected that any theory which can be proposed, will account for every circumstance connected with earthquakes and volcanoes. But that which explains the greatest number of these phenomena, is founded on the hypothesis of a "central fire," that is, a mass or masses of lava, or melted matter, deeply seated towards the centre of the earth. The two hundred volcanoes, existing in different parts of the globe, are the chimneys, or occasional outlets, of this ocean of liquid fire.

When this mass is disturbed, as by the admission of water, an earthquake is the consequence, and this becomes more or less disastrous, according to the degree of internal commotion. When the pressure of the steam, into which the water is converted, becomes excessive, then the lava is forced up one of the chimneys, and poured forth on the surface of the earth, and thus a volcano is produced, and at the same time the internal pressure is relieved.

522. *This the prevailing hypothesis.*—The hypothesis of a central fire, under various modifications, appears to be the prevailing doctrine of the geologists of the present day. "If," says Mr. Lyell, "we suppose a great number of large subterranean cavities, at the depth of several miles below the surface of the earth, wherein melted lava accumulates, and that water, penetrating into these, is converted into steam; this steam, together with the gases generated by the decomposition of melted rocks, may press upon the lava, and force it up the duct of a volcano, in the same

manner as it drives water up the pipe of a geyser. (The geyser is described under 'Silicious Springs.') But the weight of the lava being immense, the hydrostatic pressure, exerted on the sides and roofs of such large cavities and fissures, may well be supposed to occasion, not slight tremors, such as agitate the ground before an eruption of the geyser, but violent earthquakes. Sometimes the lateral pressure of the lower extremity of the high column of lava, may cause the more yielding strata to give way, and to fold themselves into numerous convolutions, so as to occupy less space, and thereby give relief, for a time, to the fused and dilated matter. Sometimes, on the contrary, a weight equal to that of the vertical column of lava, pressing on every part of the roof, may heave up the superincumbent mass, and force lava into every fissure, which, on consolidating, may support the arch, and cause the land above to be permanently elevated On the other hand, subsidences may follow the condensation of vapor, when cold water descends through fissures, or when heat is lost by the cooling of the lava."

HYPOTHESIS OF CENTRAL FIRE.

523. If this globe, towards its centre, is composed of an igneous fluid, then we might expect that the nearer we approach it, or the deeper we descend below the surface, the higher we should find the temperature, and many experiments tend to prove that this is actually the case.

524. *Baron Fourier.*—Baron Fourier, who has investigated this subject with much attention, concludes, "that the rays of the sun penetrate the globe, and occasion annual and diurnal variations in its temperature, but that these periodical changes cease to be perceptible at a certain depth under the surface. Below that depth, the temperature caused by the sun has long ceased to have any influence. If, therefore, it is found that the temperature of the deep recesses of the earth become perceptibly greater, in proportion as we recede from its surface, it is impossible to ascribe this increase to the influence of the sun, and consequently it can proceed only from the primitive heat of the earth, and with which it was originally endued. It has long since been conjectured that the heat of the earth increased in some proportion to the distance of descent from its surface; but it is only within a short

period, that experiments have been instituted, for the purpose of ascertaining whether this conjecture was well founded, and, if so, to determine the ratio of increase. With this view many mines have been accurately examined, and the fact of a gradual increase of temperature downwards, has been found general.

In the mines of Cornwall, England, Capt. Lean made the following experiments and observations, in the month of December:

At the surface, the temperature of the air was 50° Fahrenheit. At 120 feet below the surface, the air was 57°. At 600 feet below, temperature of the air 66°, of water 64°. At 962 feet below, air 70°, of water 74°. At 1,200 feet below the surface, air 78°, of water 78°.

These, with other experiments, in different mines, seemed to show that the increase of temperature, downwards, was nearly in the ratio of one degree for every sixty-five feet.

525. CORDIER'S EXPERIMENTS.—From M. Cordier, who has written a treatise on this subject, we learn that the number of mines in which experiments have been made, is about forty. These mines are situated in France, England, Switzerland, Peru, Saxony, and Mexico. The whole number of experiments made, are about 300, some being on the air of the mines, some on the water, and others upon the rocks or earth.

From all these observations, made apparently with such caution as to prevent the possibility of any considerable error, M. Cordier derives the following conclusions:

1. "If we reject a certain number of observations as uncertain, all the rest indicate, in a manner more or less certain, that there exists a remarkable increase of temperature, as we descend from the surface of the earth towards the interior. It is reasonable, then, to admit this increase.

2. "The results collected at the observatory at Paris, are the only ones that can be depended upon with certainty, for obtaining a numerical expression of the law of this increase. This expression gives fifty-one feet as the depth, which corresponds to an increase of one degree, in the subterranean temperature. And, we would remark, in passing, that, according to this result, the temperature of boiling water, under the city of Paris

would be at the depth of 8,212 feet, or about a mile and a half.

3. "Among all the other results, a small number only afford numerical expressions of the law sought for, sufficiently approximate, to be taken into account. These expressions vary from 104 to 24 feet for one degree of increase; their average, in general, indicates an increase more rapid than has generally been admitted. Their average has so much the more weight, as embracing the results of many series of long-continued observations.

4. "Lastly, in grouping together, by countries, all the results, admissible on any principle, I am led to present a new and important idea, to wit: that the difference between the results collected at different places, are referable not solely to the imperfection of the experiments, but also to a certain irregularity in the distribution of subterranean heat in different countries."

526. Cordier's Inferences.—M. Cordier describes, at length, the manner of making experiments on this subject, in order to prevent local errors; and from all that himself and others have done and written, he draws the following inferences:

1. "Our experiments fully prove the existence of an internal heat, which is natural to the terrestrial globe; which depends not on the influence of the sun, and which increases rapidly with the depth.

2. "The increase of subterranean heat, in proportion to the depth, does not follow the same law throughout the globe. It may be twice, or even thrice, as great in one country as in another.

3. "These differences are not in a constant ratio to the latitude or longitude.

4. "Finally, the increase is certainly much more rapid than has heretofore been supposed; it may be as great as twenty-seven, or even twenty-four feet for a degree, in some countries. Provisionally, however, the mean must not be put lower down than forty-six feet."

527. *No doubt of internal igneous matter.*—We must, therefore, consider it as proved, beyond all doubt, that below the crust of the earth, there exists either a mass of burning lava, or some other cause, by which there is perpetually maintained a considerable degree of heat;

and there is reason to believe that a very high temperature exists towards its centre.

That the internal temperature is caused by a melted mass, such as we have supposed to exist, is not, it is believed, incompatible with any known phenomenon; but, on the contrary, certainly accords with many of the effects already specified.

But there are other effects which are unaccountable, except on such a hypothesis; and one of these is the connection, which has often been observed to exist, between one volcano and another, and also between earthquakes and volcanoes. If there exists in the earth an extensive igneous fluid, communicating with the open air only by means of volcanic apertures, we should expect, that when this fluid by any means was set in motion, the surface of the ground would partake of such motion, and that in case this fluid should be pressed for want of room, it would be forced out at these apertures.

Now, the wave-like motion of earthquakes is a phenomenon almost universally observed; and even where the shock is slight, it produces nausea, like sea-sickness. This motion is inexplicable, if the earth is composed of solid unyielding strata; but if we suppose its crust rests upon a fluid, liable to agitation, the solution becomes natural and easy. This motion may be strikingly illustrated by covering a dish of quicksilver with sand or soil, and then giving the vessel a slight agitation.

CONNECTION BETWEEN VOLCANOES AND EARTHQUAKES.

528. The connection between volcanoes and earthquakes has been so generally observed, that no one at the present day denies that their causes must be the same. Earthquakes precede volcanoes, and when a wave of the lava reaches an aperture, there happens an eruption, and the earthquakes are diminished in force, or cease entirely, because the internal pressure is thus relieved.

529. *Proof of this connection.*—In proof of this connection, the elevation of all new islands, and the formation of all new volcanoes, and most commonly the eruptions of old ones, are preceded by, or accompanied with earth quakes, especially where the latter have some time lain dormant. The elevation of Sabrina, of the Aleutian island, of Monte Nuovo, and the formation of Jorullo,

together with what is generally known of Vesuvius and Etna, are examples.

It is true, that in some instances, earthquakes happen, both at great distances from volcanoes, and in their vicinities, without any eruption. But, when this is the case, the most calamitous consequences are produced, because the confined matter which causes the earthquakes cannot escape. This was the case, as already noticed, with respect to the earthquakes of Calabria, which destroyed 60,000 people, there being no eruption either of Etna or Vesuvius. It is probable that this was prevented by the masses of cooled lava, by which their apertures were clogged. The great earthquake of Lisbon was also unattended by volcanic eruptions.

530. MONTE NUOVO.—When the shocks commenced, which ended in the elevation of Monte Nuovo, (*Lign.* 86,) it was expected, of course, that an eruption of Vesuvius would ensue; but instead of this, after the earthquake had continued with great force for twenty-four hours, the earth opened with a tremendous noise, and, throwing out blocks of lava, pumice, and ashes, formed that mountain in 1538. Vesuvius, with a single slight exception, had remained dormant from 1306, and showed no signs of commotion during the elevation of Monte Nuovo. Now, had there been less resistance at the crater of Vesuvius, than there was on the plain, there would have been an eruption, and no new mountain would have been formed. But Vesuvius continued torpid until 1631, during which period Etna was peculiarly active, suffering frequent and terrible eruptions. This circumstance affords a strong argument in favor of a subterranean communication between these two mountains, Etna occasionally serving as an outlet for the elastic fluids and lava, a part of which would otherwise be emitted at Vesuvius, and, perhaps, the latter, in its turn, answering the same purpose during the torpid state of the former.

531. *Earthquake of Lisbon.*—Again, the earthquake of Lisbon, as already stated, was felt in all parts of Europe, and also in Africa and South America, as well as by ships sailing in the intermediate seas. Now, it cannot be reasonably supposed, that a subterranean convulsion could be communicated by the mere vibration of the earth, to the distance of so many thousand miles, and especially from

one side of the Atlantic to the other, under the ocean. If there existed no other evidence than this, of an interior fluctuating medium below the crust of the earth, it would be more philosophical, as well as reasonable, to infer that such a one did exist, than to believe that the earth was capable of transmitting a vibratory motion, however strong, to the distance of one-fourth of its circumference.

532. *Quantity of lava emitted by volcanoes.*—Finally, another proof of the existence of an immense mass of igneous matter under the surface of the earth, is the quantity of lava emitted by some volcanoes. Many instances might be adduced, but we will here only refer to that of Skaptar Jokul, in 1783, an account of which has been given. There the quantity of lava covered a surface equal to ninety miles long, and twenty broad, making an area equal to 1,800 square miles. The depth or thickness was generally about 100 feet; but, in some places, to a considerable extent, 600 feet deep. Perhaps, therefore, it would not be an over-estimate to call the average depth 150 feet. This quantity, if consolidated, would, by calculation, have formed a massive globe of about six miles in diameter.

In addition to the above, Breislak has computed the quantity of matter emitted by several other eruptions, as follows: That of Vesuvius, in 1774, was estimated at 18,000,000 of cubic feet. That of the island of Bourbon, in 1796, 54,000,000 of cubic feet. In another eruption, in 1787, the same volcano emitted, by estimation, 72,000,000 of cubic feet of lava and ashes.

Now, if the matter of this eruption came from the immediate vicinity of the mountain, it is plain that the strata under it, for six miles in extent, must have been thrown upon the surface, and a cavity produced of a proportionate size; but this is highly improbable, if not absolutely impossible, from the very nature of the case; because, if we suppose a cavity, or definite space, whence the lava proceeded, we must also suppose it constantly full of igneous matter, at least in the neighborhood of the aperture, otherwise it would not have flowed from the crater. For, we cannot believe that, in a cavity of such dimensions, steam, or any other elastic body, could have operated in such a manner as to throw out all, or the greater part of its contents.

From all we have adduced on this subject, we cannot but conclude, that the phenomena of earthquakes and volcanoes, indicate the existence of an ocean of melted lava, constantly existing at an unknown depth under the surface of the earth, and that these phenomena may, in most of their varieties, be accounted for by such a hypothesis, and by no other which has yet been proposed. It is, therefore, reasonable to infer that such a mass of igneous matter does actually exist.

CHAPTER XXXV.

ELEVATION OF CONTINENTS FROM THE SEA.

533. *Sea-shells far from the ocean.*—The occurrence of sea-shells, and the remains of marine animals, at a distance from any existing ocean, is a fact of common observation. Some of these remains are deeply buried in solid strata, while others are found in alluvia near the surface. We have noticed, in the preliminary part of this work, that such remains excited the attention of the earliest observers.

A great proportion of Italy is covered by an alluvial soil, containing sea-shells, and occasionally the remains of quadrupeds, both of living and extinct species, such as the elephant, hippopotamus, rhinoceros, mastodon, &c. In this country, in the state of New-York, of Ohio, and indeed throughout the great valley of the Mississippi, fossil shells are found; and, as in Italy, there occurs also the remains of ancient quadrupeds.

534. *American lakes once inland seas.*—The theory, long since suggested, that the great lakes of North America are the deeper beds of an inland sea, which once covered a great extent of land, a part of which is now dry, has undoubtedly many circumstances in its favor, and indeed may be considered as a well-founded geological fact. In this instance, if, as some geologists suppose, this ancient sea has been drained by the bursting of some barrier, it is

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What is said of the great American lakes having once been inland seas?

a circumstance which will account for the appearance of shells not situated higher than the bed of the former sea. But it is believed that in many places, marine organic remains are found, much more elevated than any reasonable hypothesis could have placed the bed of the former sea. The situations of these cannot, therefore, be accounted for on the supposition that they were left by the retiring waters.

535. *Bones of whales and dolphins in Italy.*—In Italy, besides the more common marine remains of shells and small fish, there are found the bones of whales and dolphins; and sometimes entire skeletons of these fish occur at the elevation of 1,200 feet above the sea.

The bones of whales, thus found, are in a high state of preservation, and are often incrusted with oyster-shells; a good proof that they have not been transported, and that the sea for a long time remained over them, after they had been denuded of their flesh.

536. *Cuvier's remarks.*—But it will be seen, by the following extract from Cuvier, that such appearances are much more common than has been supposed:

"The lowest and most level lands," says he, "when penetrated to a great depth, exhibit nothing but horizontal strata, consisting of various substances, almost all of them containing innumerable productions of the sea. Similar strata, similar productions, compose the hills, even to a great height. Sometimes the shells are so numerous, that they form, of themselves, the entire mass of the stratum. They are almost every where so completely preserved, that even the smallest of them retain their most delicate parts, their slenderest processes, and their finest points They are found in elevations, above the level of every part of the ocean, and in places to which the sea could not now be conveyed by any existing causes. They are not only enveloped in loose sands, but are incrusted by the hardest stones, which they penetrate in all directions. Every part of the world, both the hemispheres, all continents, all islands of any considerable extent, exhibit the same phenomena. They have, therefore, lived in the sea, and have been deposited by the sea; the sea therefore, must have existed in the places where it has left them."

To what elevation have the bones of fishes been found?

537. *Macculloch's remarks.*—When we find, in many parts of the world, stratified rocks forming the summits of the highest mountains, elevated many thousands of feet above the level of the sea, and when we suppose that the objects we are contemplating were once covered by water, we are strongly impressed with the changes which the relative levels of the water and land must have undergone. And when we find the remains of shell-fish imbedded in these strata, we cannot hesitate to admit that these rocks have once been covered by the ocean. When, lastly, we observe that those beds, which must once have been horizontal, are now vertical: that they are inclined, broken, bent, and dislocated in innumerable ways, we are forcibly led to conclude, that their present distance from the sea has been accompanied by violent alterations in the form of the surface, and that it has been produced by the action of enormous powers.—*Macculloch*, vol. i. p. 86.

Allowing that these strata have once been under the sea, and which, from the circumstances, is proved beyond all doubt or controversy, the question to be examined is, whether the ocean has retired to a lower level, or whether the land, by some enormous force, has not been elevated above the water.

538. *Not referable to the Deluge.*—The phenomena of shells in strata were once attributed to the Mosaic deluge; but we need not, at the present day, employ arguments to show the impossibility of such an origin. 150 days was too short a period to have produced such effects.

It has been ascertained that some of the Peruvian mountains contain sea-shells, at an elevation of 14,000 feet above the level of the sea, and that the nature of the strata in which they are contained, is such as to show that these mountains must for a long period have been submerged. Hence, it is plain that no hypothesis, connected with the deluge, can explain this fact.

Now, if the sea has retired in a gradual manner from such a height, within a period of five or six thousand years, its level ought now, at this rate of depression, to be at least four thousand feet lower than it was two thousand years ago; but facts, with respect to the Baltic and the Mediterranean, tend to prove, that since the Christian

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Are these phenomena referable to the Deluge?

era, the ocean has not changed its level, in any appreciable degree.

539. There is, therefore, not the least probability, or even possibility, that marine organic remains situated above the sea, or imbedded in strata at a distance from it, can be accounted for by any supposition connected with the depression of the waters of the ocean.

540. *Evidence of the elevation of the land.*—If now we examine the facts and arguments, tending to show that the land has been thrown up from the bottom of the sea, we shall find that the evidence amounts to little less than absolute demonstration that this has been the case.

In the first place, strata composed of fragments of rocks of any considerable size will take the horizontal direction. It is true that deposits of fine matter, as clay and sand from water, will at first take the impression or form of the bottom, when this is uneven; but if the strata be of any considerable thickness, the layers will assume a horizontal level. But we shall find, on examination, that very few stratified rocks, in any part of the world, have preserved their coincidence with the horizon. On the contrary, they are inclined at various angles, and are sometimes even quite vertical; clearly evincing that they have been disturbed, and dislocated by some violence, since their formation.

"If," says Dr. Macculloch, "the highly inclined position of strata were not itself a proof of their elevation, evidences of motion are found in a great number of phenomena. In their curvatures we find proofs of disturbance; we find even more decided evidences to the same purpose, in their fractures. But when we see that these fractures are accompanied by a separation of parts which were once continuous, that one portion of a stratum occupies a higher or lower place than another, and that this separation is often attended by a difference in the angle of inclination of the separated parts, we have every proof that can be desired, of an alteration in the horizontal position of stratified rocks since the period when they were consolidated." —*Geology*, vol. i. p. 88.

In the kind of materials of which many inclined strata are composed, we have additional evidence of their elevation.

What is the evidence of the elevation of the land?

We have stated that depositions of sediment from water will at first take the form of an uneven bottom; but we need not stop to prove, that fragments of rock of any considerable size, will not rest on the sides of steep declivities, but will roll or slide down by their own gravity. Now, "it is notorious," says Dr. Macculloch, "that the conglomerates which form such conspicuous strata in many countries, and which prevail chiefly at the boundary which separates the strata called secondary, from the primary, are often found in positions, not only highly inclined, but absolutely vertical. As the materials of these are often of such bulks as to weigh even many hundred pounds, it is evident that the original position of the strata which contain them must have been horizontal."

541. *Evidence by marine worms.*—It it is well known, also, that certain marine worms, which live in sand and inhabit straight tubular shells, invariably penetrate the sand in a vertical direction, whether the surface be horizontal or not. If the strata remain undisturbed, these shells remain in the position seen at *Fig.* 1.

LIGN. 106.

Fig. 1. Fig. 2.

Tubular shells.

And it needs little reflection to see that a concave, or dish-formed shell, when it sinks in water, must reach the bottom with its convexity downwards; and hence, in all recent formations, such shells are always found in this position. But in the inclined strata, of which we are speaking, such tubular shells are found making various angles with the horizon, though they preserve their perpendicularity with respect to the strata: as represented at *b. Fig.* 2; while had the strata been pierced after its disturbance, it would have been in the direction of *c.* The concave shells, under like circumstances, are found to have changed their positions, their cavities being no longer

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What evidence of elevation do marine worms offer?

upward, but inclined according to the position of the strata. On the same subject, Dr. Ure says: "The erection of subaqueous strata into primitive mountains and plains, was evidently accompanied with universal disruption. Innumerable fragments of both the upborne and upbearing rocks were tossed about, and washed down into the congregated waters, along the precipitous shores, and over the beds of the primeval ocean. These shattered fragments, becoming agglutinated by their own pulverulent cement, soon recomposed continuous strata, which bear internal evidence of the violence which gave them birth. Thus were formed the *transition* rocks of geologists, mineral masses, which denote the passage between the upright primitive, and the horizontal secondary strata, between those of inorganic and organic evidence."

LIGN. 107.

Pebbles, (oblique.)

542. *Vertical beds of pebbles.*—The convulsions which after a long interval caused the deluge, have dislocated many of these conglomerates, so that strata of rounded pebbles assuredly agglutinated in a horizontal position, are now found standing in upright walls. Thus the

How do vertical beds of pebbles show the elevation of the land?

famous pudding-stones of Valorsine, in Savoy, are a kind of graywacke shist, containing rounded fragments of gneiss and mica-slate, six or seven inches in diameter. That stones, previously rounded by attrition, should build themselves up into a nearly perpendicular wall, as seen at *Lign.* 107, and stand steadily thus, till fine particles of hydraulic cement should have time to envelop and fix them in their places, is an absurd and impossible supposition. It is, therefore, demonstrable that these pudding-stone strata were formed in horizontal, or slightly inclined beds, and erected after their accretion. Such effects would be produced, in the convulsive emergence of the pebbly banks out of the primeval ocean, either at the general, or by some preceding catastrophe. There are mountains 10,000 feet high, in the Alps, formed of firmly conglomerated pebbles.

543. *Elevation of the hypogene rocks.*—Another and most striking proof that the rocks have been elevated by some force acting beneath them, is exhibited by primitive mountains in various parts of the world.

Here we find granite in the centre, with stratified rocks, as gneiss, mica-slate and clay-slate, leaning against its sides, sometimes nearly in a vertical position. Now, as these stratified rocks must have been deposited on a horizontal level, or nearly so, and surely not in the highly inclined positions in which they are found, it is evident that their original positions must have been changed, and their inclinations caused by the same force which elevated the primitive mountains.

Under the article, "Classification of Rocks," this subject is illustrated by a wood cut, *Lign.* 71, to which the reader is referred.

It thus appears sufficiently evident, that at least a great proportion of the habitable earth was formed in strata under the sea; and that subsequently to its being consolidated, chiefly in the position and form of horizontal layers, it has been violently elevated above the water, by some tremendous subterranean power. Hence, the strata are found oblique, dislocated, and rent asunder in nearly every part of the world; and from this cause it is, that the sea and land have exchanged places, and the mountains have been elevated; but to the same cause, even to the destruction of that continuity and harmony which

seems to have existed in the form of the primitive globe, we must attribute many of the greatest conveniences and comforts which the present earth now affords.

544. *Benefits of these dislocations to man.*—Had no disturbing forces interposed, there is reason to believe that the inferior strata, now in many places elevated into hills and mountains, would for ever have been concealed from the knowledge of man; for was the earth every where covered with horizontal strata, lying in regular layers, one upon another, the same kind of formations would every where exist; and of which we should know nothing below the depth of actual excavations. *Metallic veins, salt*, and *coal*, would afford no indications of their existence at, or near the surface. There would have been no mural precipices, or mountain declivities, or out-croppings of strata, by which the geologist, or practical miner, would be enabled to judge of the interior. Nor would there have been any springs of water issuing from the surface of the earth, for it is the inclination of the strata which directs the water to the surface, and its unevenness, which allows it to break forth in the form of springs. In plain level districts, no water rises to the surface. In these, and many other examples which might be noticed, we cannot but see the traces of benevolence and design, even in the "wreck of matter," which this earth every where displays; and which, at every step, forces us to acknowledge, not only the power, but the wisdom and kindness of the Almighty Builder of this, our habitation.

545. *The agent, undoubtedly volcanic action.*—With respect to the agent which has thus thrown mountains and continents from the depths of the ocean, and has dislocated the framework of the globe, we can conceive of none, except *volcanic*, of sufficient power to produce such effects. It is true that no continents, or extensive mountains, have been elevated from the sea, since the historical era, but we have a sufficient number of examples of the effects of this power, even during the present age, to show that the established order of nature would not be changed by the elevation of a continent. The elevation of land to the extent of a hundred miles on the coast of Chili; the rising of the Sabrina island out of the ocean; and of the

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How have these dislocations been of use to man?

Aleutian islands on the coast of Kamschatka, out of the same; the changes made by the force of volcanoes in the neighborhood of Naples, and the effects of the earthquakes of Calabria and Lisbon, (all of which we have described in the preceding pages,) afford analogies by which it is not unreasonable to conclude, that it was the same kind of force which broke in pieces the crust of the primeval globe, and raised the habitable earth from the ocean's bed.

At what period of the creation these great changes took place, we must remain in ignorance, but it is improbable that they were all effected at the same time. On the contrary, the appearance of the strata seems to indicate a succession of revolutions at different, and perhaps remote periods from each other. These revolutions appear to have been before the creation of man and animals, and probably by such means did the wisdom and benevolence of the Creator prepare a place for their reception and comfort.

PART V.

EFFECTS OF CAUSES NOW IN OPERATION.

CHAPTER XXXVI.

AQUEOUS CAUSES.

546. Having described the effects of igneous forces in effecting changes on the crust of the earth, we now come to the consideration of some of those changes which have been produced by the action of water.

As we have already seen, the earth almost every where presents satisfactory proof of having undergone great and terrible changes, and which geologists all coincide in believing, have been the effects of volcanic action, at some remote period; but no positive evidence of either cause or effects can be produced on this subject at the present day, since no high mountains or deep valleys have been formed, within the age of history. But it is quite certain that these changes in the earth's surface have not been produced by any general causes now in operation.

547. *Local causes will not account for the effects produced.*—It is true, that in a few instances, local causes have produced considerable changes within confined limits, as where volcanoes have raised craters, and extraordinary floods of water have made excavations, both within the memory of man, or within the epochs of history; but these causes, though supposed to have operated constantly, from the remotest period which the imagination can suggest, will fail to account for the changes which it is evident the earth has undergone, since the stratified rocks were deposited and living existences created. We may hence conclude, either that the causes which produced such mighty effects have entirely ceased,

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What is said of the changes in the earth's surface being produced by existing causes?

and are unknown to us, or that they operated with infinitely greater force formerly, than at present.

It being one of the chief objects of geology to point out the changes which the crust of the earth has undergone, and, if possible, to account for these, it becomes necessary that the causes now operating, the effects of which are apparent, should be described and distinguished from those, the effects only, not the causes of which, are certainly known at the present time.

GENERAL EFFECTS OF RUNNING WATER.

548. *Aqueous effects of mountains.*—It is well known that mountains, or lands elevated far above the level of the sea, attract the moisture of the atmosphere, in some proportion to their elevation. By this provision, the higher regions of the earth become perpetual reservoirs of water, which descend and irrigate the plains and valleys below. Thus, a great proportion of the water which falls upon the earth, is carried first to the higher regions; and then made to descend, often by steep declivities, towards the sea; so that it acquires a rapid velocity, and removes a greater quantity of soil, than it would do if the rain was equally distributed on the mountains and plains. Thus, without reference to the disintegration or decay of rocks, the water constantly transports more or less soil and gravel from the hills to the plains.

549. *Mechanical effects of water.*—Among the most powerful agents in effecting the decay of rocks, is the mechanical action of water, especially in cold climates. It is well known that water expands in the act of freezing. The effect of this expansion is so powerful as to burst bombshells, and large cannon, when closely confined in them. When, therefore, water falls into the fissures of rocks, and there freezes, the rocks are rent apart with the force of a powerful lever; and the more porous ones are divided into small pieces. These are often further divided by the frequent fall, and consequent crushing and grinding motion of one rock on another on the declivities of the mountains. Water also has the power of dissolving considerable quantities of some kinds of rocks, especially those of the limestone and gypsum kinds. The oxygen of the atmosphere

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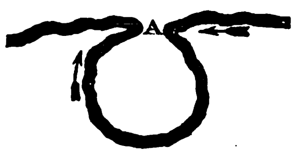
What are the mechanical effects of running water?

is another cause of the decay of rocks. "This element is gradually absorbed by all animal and vegetable substances, and by almost all mineral masses exposed to the open air. It gradually destroys the equilibrium of the elements of rocks, even the hardest aggregates belonging to our globe."—*Sir H. Davy.*

LIGN. 108.



Running water.

550. *Attrition of running water.*—When earthy matter has been once mixed with running water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along by the violence of the stream. Rapid streams, charged with foreign matter, and thrown against their rocky sides, will, in the course of time, produce excavations in consequence of which, rocks are often undermined, and precipitated into their beds. The water being thus obstructed, accumulates, and cuts for itself a new channel, taking with it an additional quantity of earth. In this manner, also, the stream is often made to take a new direction, perhaps obliquely across the valley through which it runs. The unequal hardness of the soil is another cause of change in the direction of streams, and so also are logs of wood, leaves, and other matters, with which streams are often charged. When from these, or other causes, a current is made to deviate from its course, it gradually wears a curve into the opposite bank, where the water for a moment accumulates, and then, receiving a different direction from the lower side of the curve, shoots across to the opposite side, where a similar curve is soon formed, and the water made to recross the channel as before. Thus, we often see brooks and rivers crossing and recrossing the valleys through which they run, many times; and sometimes, after taking a wide sweep, returning again nearly to the point where the same water had

passed, an hour, or many hours before. When this happens, and every one has seen such instances, it is often the case that during some overflow of the stream, the water cuts across the isthmus at A, as seen by *Lign.* 108, and thus forms an island. In consequence of this, the water not only takes a new direction at that particular point, but often the foundation is thus laid for considerable changes below the island.

551. *Fertile valleys formed by rivers.*—These serpentine windings, not only take place in trout brooks, but in the largest rivers, and thus become the means of leveling and fertilizing tracts of country, of greater or less extent. The Mississippi, through a considerable part of its course, cuts across its immense valley in the manner here described, and sometimes, after running ten or twenty miles, returns back again nearly to the same point. The fertile valley of the Connecticut has been formed, in a great measure, by the same means The rich meadows, now every year irrigated by its waters, have been formed, in the course of time, by the changes of its bed. This is shown by the logs of wood uncovered in its banks by every new change its current makes at the present time. Charcoal and other organic substances, have been found 20 feet below the present surface of its banks.

552. *The buoyancy of water in transporting rocks.*—In estimating the transporting power of water, we are apt to forget its buoyancy; and on which, indeed, its power of moving heavy substances, such as rocks, in a great measure depends. The specific gravity of many rocks is little more than twice that of water, that of granite and limestone being about 2.50, that is, two and a half times, bulk for bulk, the weight of water. Hence, a stone, weighing twenty-five pounds in the air, or under ordinary circumstances, will weigh only fifteen pounds when immersed in water. Those who have never tried the experiment of lifting a stone under water, will be surprised to find with what ease he can raise a block of granite to the surface, above which, however, with all his efforts, he cannot lift it. If a man can lift a stone weighing one hundred pounds whose specific gravity is two, in the air, he can lift one weighing two hundred pounds in the water, because the

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How are fertile valleys formed by rivers? What proportion of a rock does the water lift?

fluid lifts just one-half of its weight. It is from our not taking this circumstance into account, that we are often surprised at the power of torrents to move stones of great size.

553. *Effects of the velocity of water.*—According to experiments recorded in the *Encyclopedia Britannica*, a velocity of water equal to three inches per second is sufficient to tear up fine clay; six inches per second, fine sand; twelve inches per second, fine gravel; and three feet per second, small stones. It is obvious, however, that the depth of the water will influence these results, and that the power of moving bodies will be in proportion to its depth and velocity.

Since the time of historical records, the power of running water has produced many and great changes in various parts of the world. In some instances, lakes have been filled up; in others, deep ravines have been formed; in others, whole districts have been ruined in consequence of rivers having changed their beds, and in others, considerable tracts of land have been accumulated, or sometimes swept away, by the force of mountain torrents.

EFFECTS OF THE RIVER PO.

554. The Po affords a grand example of the manner in which a great and rapid stream, bears down to the sea the alluvial matter poured into it by a multitude of tributaries, descending from lofty chains of mountains. The changes gradually produced by this river, in the great plains of Northern Italy, since the time of the Roman Republic, have been exceedingly disastrous to some parts of that country. Extensive lakes, and marshes, have been slowly filled up, as those of Placentia, Parma, and Cremona, while others have been drained by the same cause. Since 1390, the Po deserted its bed through a part of the territory of Cremona, and invaded that of Parma, its old channel being still obvious, and retaining the name of *Po morto*, or dead Po. The town of Bressello, which formerly stood on the left bank of the river, now stands on the right; the river, not the town, having changed its locality. In the ancient parish records it is stated, that several churches were taken down, and afterwards rebuilt at a greater dis-

What is said of the effects of the Po, in transporting solid matter?

tance from the new bed of this devastating stream; and in 1471, the friars of a monastery pulled down their edifice, and erected it at a greater distance from the Po.

555. *Embankment of the Po.*—To keep this wild stream within bounds, a general system of embankment through the plains of Northern Italy, was commenced in the thirteenth century, which has continually been increased until the present time. The increased velocity of the river, in consequence of its being thus confined, causes it to transport to the sea a much greater quantity of alluvial matter than it would otherwise do, because there are no sluggish intervals where its waters can deposit their sediment. Hence, the delta of the Po, even since the memory of man, has greatly increased. The ancient city of Adria was originally a sea-port of the Adriatic, but it is now twenty miles from the shore. In the twelfth century, Adria was about six miles from the shore, the Po having added fourteen miles of alluvial soil since that period.

But notwithstanding more alluvial matter is carried into the sea in consequence of this embankment, more is also deposited in its bed; for that which would be spread upon the plains during an overflow, is now confined within the narrow limits of its banks. In consequence of this constant deposition, it is found necessary every year to remove the mud and sand from the bed of the river, and place it on the embankment; otherwise the water would be in danger of breaking through, and destroying the whole plain below.

This system has been so long continued that, at the present day, the Po crosses its plains to a considerable distance, on the top of a high and continued mound, like the waters of an aqueduct, and to the great hazard and terror of the people in the valleys, every spring.

M. de Prony, who has recently been employed by government to examine the present condition of this river, and, if possible, to suggest some method of security against a catastrophe which every year threatens the lives and property of so many inhabitants, ascertained that the bed of the Po is now higher than the roofs of the houses in the city of Ferrara, near which it runs. The magnitude of these barriers, already so immense, it is found necessary to increase every year, to prevent an inundation.—*Lyell and Cuvier.*

When we consider that the smallest stream, breaking through or running over this embankment, would, if not discovered within a few seconds, destroy, in spite of all human power, many cities, towns, and villages, with ali their inhabitants, we may in some degree conceive of the constant anxiety which those must feel who reside within the danger.

FALLS OF NIAGARA.

556. This is the most magnificent water-fall in the world. It is situated between lake Erie above, and lake Ontario below; the cataract being formed by the passage of the water from one lake to the other. The distance between the nearest shores of these lakes is about thirty-seven miles, and the height of Erie above Ontario is, according to Mr. Featherstonhaugh, 322 feet. On flowing out of the upper lake, the river is almost on a level with its banks, so that, if it should rise perpendicularly eight or ten feet, it would lay under water the adjacent flat country of Upper Canada on the west, and part of the state of New York on the east. The river where it issues, is about twenty-five feet deep, and three quarters of a mile wide. Its descent is fifty feet in half a mile. Goat island, at the very verge of the cataract, divides the water into two parts. The stream on the American side is 1,072 feet wide; and the curvature of the great Horse-shoe fall is 2,376 feet wide; making the width of the whole at the falls, 3,448 feet.

Although the aggregate descent from Erie to Ontario is 322 feet, the perpendicular fall at the cataract is less than one-half this distance.

The following particulars are from Mr. Featherstonhaugh's journal:

	feet.		miles.
Fall from Erie to the rapids above the Cataract of Niagara,	15	in	23
Fall of the rapids to the edge of the Cataract,	51		½
Fall of the Horse-shoe Cataract,	150		
From Horse-shoe fall to Lewiston,	104		13
From Lewiston to Ontario,	2		
	322		36½

Where are the falls of Niagara? What is the height of Erie above Ontario?

557 *The falls once at Queenston.*—There is no doubt but the Falls of Niagara, at some remote period, were at Queenston, which is about seven miles below their present situation. The breadth of the gorge or excavation made by the waters, is, on approaching the falls, about 1,200 feet, but is much narrower towards Queenston.

The kind of rock through which it passes consists of limestone and shale, the latter a dark-colored shelly formation, 80 feet thick, lying under the limestone. The limestone is 70 feet thick, above which is the ordinary soil of the country.

The limestone is hard, and lies in horizontal strata at the edge of the falls; but the shale is soft, and is acted upon with much greater facility than the limestone, so that the latter rock often overhangs the former, perhaps forty feet at the edge of the precipice.

The blasts of wind charged with spray, which rise out of the pool into which this enormous cascade is projected, strike against the shale beds, so that their disintegration is constant; and the superincumbent projecting limestone, being left without a foundation, falls from time to time in immense rocky masses. When these enormous fragments fall, a shock is felt, often at considerable distances, accompanied by a noise resembling a distant clap of thunder.

The waters, which expand at the falls, where they are divided by the island, are contracted again after their union into a stream, averaging not more than 500 feet broad. In the narrow channel, immediately below this immense rush of waters, a boat may pass across the stream with safety. The pool into which the cataract is precipitated, being 170 feet deep, the descending water sinks down, and forms an under current, while the superficial eddy carries the upper stream back *towards* the main fall. (*See Mr. Bakewell, Jr., on the falls of Niagara, London Magazine*, 1830.)

558. *Mr. Lyell's estimates.*—Mr. Lyell, who refers the changes which have taken place on the earth's surface to "causes now in operation," states that the recession of the falls has been at the rate of *fifty yards in forty years*, and therefore a little more than three feet on an average in each year.

At what place is it said the falls were once situated?

If the ratio of recession, says he, "had never exceeded fifty yards in forty years, it must have required nearly *ten thousand* years for the excavation of the whole ravine; but no probable conjecture can be offered as to the quantity of time consumed in such an operation, because the retrograde movement may have been much more rapid when the whole current was confined within a space not exceeding a fourth, or a fifth, part of that which the falls now occupy. Should the erosive action not be accelerated in future, it will take upwards of thirty thousand years for the falls to reach lake Erie (twenty-five miles distant) to which they seem destined to arrive in the course of time, unless some earthquake changes the relative levels of the districts. The table-land extending from lake Erie, consists uniformly of the same geological formations as are now exposed at the falls. The upper stratum is an ancient alluvial sand, varying in thickness from 10 to 140 feet; below which, is a bed of hard limestone, about 90 feet in thickness, stretching nearly in a horizontal direction over the whole country, and forming the bed of the river *above* the falls, as do the inferior shales *below*. The lower shale is nearly of the same thickness of the limestone."

559. "Should lake Erie remain in its present state until the period when the ravine recedes to its shores, the sudden escape of that great body of water would cause a tremendous deluge; for the ravine would be more than sufficient (in depth, we suppose,) to drain the whole lake, of which the average depth was found, during the late surveys, to be ten or twelve fathoms."—*Lyell's Geology*, vol. i. pp. 179–182.

Although Mr. Lyell owns that no probable conjecture can be afforded with respect to the time which has elapsed since the falls of Niagara were at Queenston, still, it is obvious that the impression intended to be left on the mind of the reader is, that it was about 10,000 years ago; that is, about 4,000 years before the creation, according to Moses, these falls were at Queenston. And at some future period, say 30,000 years hence, there will be a great flood in America, just as there have happened great floods at different periods, according to what he calls the "uniformity of the order of nature."

Now, let us see, in the first place, whether the data stated by the author can possibly warrant the supposition.

that the falls of Niagara have been 10,000 years, or even half that time, in passing from Queenston to their present location.

Mr. Lyell, who quotes Capt. Basil Hall for his authority, makes the falls 800 yards wide at the verge of the precipice; viz: the American fall 200 yards, and the Horseshoe fall 600 yards wide. The channel below the falls towards Queenston, according to the same authority, is 160 yards wide. Mr. Featherstonhaugh, (*Monthly American Journal*, No. 1,) we have already seen, makes all these widths more considerable. But we will take Mr. Lyell's own account.

560. The old channel, being 160 yards wide, is exactly one-fifth the width of the present falls. Now, supposing the retrograde movement of the cataract had been in proportion to its width, then, according to Mr. Lyell's estimate, it could have been only 2,000 years in traveling from Queenston to its present place; for 160 being a fifth of 800, and allowing the present movement to be at the rate of 7 miles in 10,000 years, then, being only a fifth as wide, anciently, as now, there is reason to believe that it moved at least five times as fast. But reasoning from the data before us, the time must have been even less than 2,000 years; for it is plain that a given quantity of water, say a yard in breadth, would perform the work of excavation more than five times as rapidly as it would if spread over five yards in breadth. It is, however, but fair to state, that the falls at Queenston were not so high as they are at present; and therefore, estimating the quantity of water the same as at present, the movement must have been slower than now. For we know that the denudating, or excavating power of water, bears not only a proportion to its depth and rapidity, but also to the height from which it falls; so that cataracts of little elevation produce no perceptible effects for centuries, while, if the same quantity of water were precipitated from a height of several hundred feet, the whole precipice would gradually retrograde up the stream. Allowing, therefore, that the falls moved only at half the rate above estimated, this would fix the time at 4,000 years since they were at Queenston.

561. *Mr. Lyell's personal examination of the Falls of Niagara.*—In 1842, Mr. Lyell visited, in person, the Falls of Niagara, and it cannot but be interesting to every in-

quirer on such subjects to know the opinion of so celebrated a geologist, on the most magnificent cataract in the world. We therefore make the following extract from his travels in North America:

"The next inquiry into which we are naturally led by our retrospect of the past history of this region, relates to the origin of the Falls. If they were once seven miles northward of their present site, in what manner, and at what geological period, did they first come into existence?" I shall endeavor to show, in a subsequent chapter, when speaking of Canada, that this drift (previously mentioned) was of marine origin, and formed when the whole country was submerged beneath the sea. In the region of the Niagara, it [the drift] is stratified, and though no fossils have as yet been detected in it, similar deposits occur in the valley of the St. Lawrence, at Montreal, at a height nearly equal to Lake Erie, where fossil shells, of species such as now inhabit the northern seas, lie buried in the drift.

"It is almost superfluous to affirm, that a consideration of the geology of the whole basin of the St. Lawrence, and the great lakes, can alone entitle us to speculate on the state of things which immediately preceded, or accompanied the origin of the great cataract. To give even a brief sketch of the various phenomena to which our attention must be directed, in order to solve this curious problem, would require a digression of several chapters. At present, the shortest and most intelligible way of explaining the results of my observations and reflections on this subject, will be to describe the successive changes, in the order in which I imagine them to have happened."

562. *Elevation and submergence of the land.*—" The first event then to which we must recur, is the superficial waste or denudation of the older stratified rocks, all of which had remained nearly undisturbed and horizontal, from the era of their formation beneath the sea to a comparatively modern period. That they were all of marine origin is proved by their imbedded corals and shells. They at length emerged slowly, and portions of their edges were removed by the action of the waves and currents, by which cliffs were formed at successive heights, especially where hard limestones, as at Blackrock and Lewiston, were incumbent on soft shales. After this denudation, the whole

region was again gradually submerged and this event took place during the glacial period, at which time the surface of the rocks already denuded were smoothed, polished, and furrowed by glacial action. The country was then buried under a load of stratified sand, gravel, and erratic blocks, occasionally 80, and in some hollows more than 300 feet deep. The period of submergence last alluded to was very modern; for the shells then inhabiting the ocean belonged, almost without exception, to species still living in high northern, and, some of them, temperate latitudes."

563. *Intermittent rëemergence of the country.*—"The next great change was the rëemergence of this country, consisting of the ancient denuded rocks, covered indiscriminately with modern marine drift. This upward movement was not sudden and instantaneous, but gradual and intermittent. The pauses by which it was interrupted are marked by ancient beach lines, ridges, and terraces, found at different heights above the present lakes."

Formation of the cascade at Queenston.—"As soon as the table-land between Lake Erie and Ontario emerged, and was laid dry, the river Niagara came into existence, the basin of Lake Ontario still continuing to form a part of the sea. From that moment there was a cascade at Queenston, of moderate height, which fell directly into the sea. The uppermost limestone and subjacent slate, being exposed, the cataract commenced its retrograde course, while the lower beds were still protected from waste by remaining submerged."

Mr. Lyell supposes that, besides the fall at Queenston, there were two others, between that place and where the Falls now are, and that in process of time, they have all united, by the action of the water on the rocks below, thus forming one grand cataract.—*Travels*, vol. i. pp. 38–40.

AMERICAN DELUGE.

564. With respect to the deluge, which Mr. Lyell predicts will happen about 30,000 years hence in North America, we will state the grounds on which his profoundly scientific vision presages a catastrophe so awful to this devoted country.

"It was," says he, "contrary to analogy to suppose that nature had been, at any former epoch, parsimonious of time,

and prodigal of violence, to imagine that one district was not at rest while another was convulsed; that the disturbing forces were not kept under subjection, so as never to carry simultaneous desolation over the whole earth, or even over one great region." ****. "In speculating on catastrophes by water, we may certainly expect great floods in future, and we therefore presume that they have happened again and again in past times. The existence of enormous seas of fresh water, such as the North American lakes, the largest of which is elevated more than 600 feet above the level of the ocean, and is in part 1,200 feet deep, is alone sufficient to assure us, that the time will come, however distant, when a deluge will lay waste a considerable part of the American continent. No hypothetical agency is required to cause the sudden escape of the confined waters. Such changes of level and opening of fissures, as have accompanied earthquakes since the commencement of the present century, or such excavations of ravines as the receding cataract of Niagara is now effecting, might break the barriers. Notwithstanding, therefore, that we have not witnessed within the last 3,000 years the devastation by deluge of a large continent, yet as we may predict the future occurrence of such catastrophes, we are authorized to regard them as part of the present order of nature, and they may be introduced into geological speculations respecting the past, provided we do not imagine them to have been more frequent or general than we expect them to be in time to come."—*Principles of Geology*, vol. i. p. 88.

565. Mr. Lyell's argument runs thus: "Because there are great lakes in North America, situated 600 feet above the sea, and because the cataract of Niagara is receding towards these lakes at the rate of fifty yards in forty years; therefore, we may anticipate great floods in future, and we therefore presume that they have happened again and again in past times." Consequently, we must presume that all the changes the earth has undergone by water, have been produced by such catastrophes, and therefore Noah's flood never happened, and so the Mosaic history is not to be believed.

It is plain that Mr. Lyell's zeal to show that there has been no universal deluge, made him forget, that in another part of his volume, he states that the quantity of sediment

which is every year deposited in lake Erie, is such, that it will finally be filled up, and become dry land; and as he does not expect the cataract of Niagara will drain this lake until the end of 30,000 years, we may hope that it will become solid within that period.

But independently of this oversight, no person of the least reflection, whether geologist or not, would for a moment believe that a lake, formed like a dish, and surrounded on all sides by solid limestone rocks, 90 feet thick, as Erie is, could be drained to its bottom in a few hours by the action of its own waters. Suppose the cataract of Niagara now at the outlet of lake Erie, and moving into it at the rate of 50 yards in 40 years, or a little more than a yard per year, we would inquire of Mr. Lyell how long a period would be consumed in draining it to the bottom, and whether the escape of its waters thus *sudden*, "would cause a tremendous deluge," as he asserts.

MOUNTAIN SLIDES.

566. Instances have happened in various parts of the world, where considerable changes have been produced in the surface of the globe, by the sliding of large portions of earth, together with fragments of rocks, from the declivities of mountains. These changes are readily distinguished from those occasioned by the general deluge, not only by their local and more recent appearance, but also by the direction in which these precipitated rocks remain with respect to the range of the mountain from which they have fallen. For the great currents of the deluge left their effect in lines corresponding with the ranges of most of the high mountains and considerable valleys, where they are still to be seen; whereas, occasional slides leave their effects at the feet of the mountains, in piles, or downward ranges.

SLIDE OF THE WHITE MOUNTAINS.

567. The White Mountains are situated in New Hampshire, and are the highest land in New England. The slide to be described took place in August, 1826, and was in consequence of the fall of an immense quantity of rain on the mountain.

On both sides of the river Saco, innumerable rocks and stones, many of them of sufficient size to fill a common

apartment, were detached; and, in their descent, swept down before them, in one promiscuous and frightful ruin, forest shrubs, and the earth in which they grew. No tradition existed of any similar catastrophe at former times, and the growth of the forests on the flanks of the mountain, clearly proved that, at least for a long interval, nothing similar had occurred. One of these moving masses was afterwards found to have slid three miles, consisting of rocks, earth, trees, &c., with an average breadth of a quarter of a mile. The excavations commenced generally in a trench, a few yards in depth, and a few rods in width, and descended the mountain, widening and deepening, until they became vast chasms. Forests of spruce and hemlock were apparently prostrated with as much ease as if they had been fields of grain. The valleys of the rivers Amunoosuck and Saco, presented for many miles an uninterrupted scene of desolation; all the bridges being carried away, and the ground strewed with the wrecks of trees and rocks, and in many instances large quantities of soil. In some places the road was excavated to the depth of 15 or 20 feet; and in others, it was covered with rocks, trees and soil, to as great a height. In various places, as shown by the remaining marks, the water rose to the height of 25 feet above its ordinary level.

But these things are of little consequence, when compared with the human suffering which this catastrophe occasioned; for a family of nine persons was destroyed on the night of the 28th, and not one lived to relate the circumstances.

This family, named Willey, occupied a house at the foot of the mountain, a most lonely place, six miles from any other human habitation. It was a resting-place for travelers. On the morning of the 28th, the house was found standing, but not a human being was there. In the course of a few days, seven out of the nine bodies were found at a short distance below the house, buried under the ruins of the mountain, and most of them shockingly mangled. It appeared that one of the heaviest slides from the top of the mountain, had rushed in the most impetuous manner towards the house, but when within six feet of it, had divided, and passed on each side, leaving the house untouched, but sweeping away the

stables and horses. At this time it is supposed that the family left the house, and met their destruction; had they remained, all would have been safe.—*Silliman's Journal for January*, 1829.

568. FLOOD IN THE VALLEY OF BAGNES, IN 1818.—The Valley of Bagnes forms a part of the main valley of the Rhone, above the lake of Geneva, in Switzerland. Through this valley passes the river Dranse, which falls into the Rhone, above the lake. In 1818, in consequence of the fall of avalanches, the Dranse was completely dammed up, so that a barrier of ice remained across its channel, until the melting of the snow in the spring formed a lake in its bed, a mile and a half in length, about seven hundred feet wide, and in some places two hundred feet deep. To prevent the consequences apprehended from the sudden bursting of this barrier, the people cut a tunnel through it, several hundred feet in length, before the water had risen to any considerable height. When the water had accumulated so as to reach this tunnel, or gallery, it ran through, and melting the ice, it drained off about one half of the lake. But at length, on the approach of the hot season, the central portion of the remaining mass of ice gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. In the course of its descent, the water encountered several narrow gorges, and at each of these it rose to a great height, and then bursting its barriers, rushed forward with increased violence, sweeping along rocks, houses, trees, bridges, and cultivated lands. For the greater part of its course, the flood resembled a moving mass of rocks and mud, rather than of water. Some fragments of primary rock, of enormous magnitude, and which, from their dimensions, might be compared, without exaggeration, to houses, were torn out of a more ancient alluvion, and borne down for a quarter of a mile. The velocity of the water, in the first part of its course, was thirty-three feet per second, which diminished to six feet, before it reached the lake of Geneva, where it arrived in six hours, the distance being forty-five miles.

This flood left behind it, on the plains of Martigny, thousands of trees torn up by the roots, together with the fragments of many buildings. Some of the houses in the town of Martigny, were filled with mud, up to the second

story. After expanding in the plain, where the town stands, it passed into the Rhone, and did no further damage. Many lives were destroyed by this flood, and the bodies of several persons were found on the surface of the Geneva lake, 30 miles from the place where they were swept away.

CHAPTER XXXVII.

CHANGES EFFECTED BY SPRINGS.

The theory of springs will be reserved for another place. At present, our object will be to show the effects which springs have had in changing the surface of the globe.

569 *Calcareous tufa, or travertine.*—It is obvious that springs of pure water, unless uncommonly powerful, will produce but little effect on the surface along which they run, and, with a few exceptions, their excavating effects are scarcely to be taken into account. But springs which contain carbonic acid gas, often hold considerable quantities of calcareous matter in solution, and which is deposited along their courses, producing what geologists term *calcareous tufa*, or *travertine*.

These deposits are generally porous, and mixed with leaves, bits of wood, mud, &c., but when more pure, they are so solid as to be employed for building-stones. Many of these springs are *thermal*, or warm, and abound chiefly in volcanic countries.

In those parts of France and Italy which skirt the Appenines, innumerable mineral springs, chiefly containing carbonate of lime, issue from the ground. As the water evaporates, the lime is left on the surface, and thus the ground in some parts of Tuscany is covered to a considerable extent with the kind of deposit called travertine, already noticed. In some places these deposits are solid, and smooth on the surface, much resembling currents of lava.

BATHS OF SAN VIGNONE.

This spring is also in Tuscany, and affords a striking example of the rapid precipitation of carbonate of lime from thermal waters. The spring issues from near the summit of a hill, about one hundred feet high. The water is hot, but Mr. Lyell, from whom this account is taken, does not give its temperature.

So rapid is the deposition from this water, that a pipe, leading from the spring to the baths, and inclined at an angle of thirty degrees, is found to contain a coat of solid limestone, half a foot thick, every year. A mass of solid rock, below the hill, formed by this water, is two hundred feet thick. This is employed as a building-stone, and in quarrying it, Roman remains of art, such as tiles, have been found five or six feet below the surface, being covered by the deposit.

BATHS OF SAN FILIPPO.

These baths are situated only a few miles from those already described. The waters which supply them are impregnated with carbonate of lime and sulphate of lime, (gypsum.) They flow from the spring immediately into a pond, where in *twenty* years a solid rock is deposited, *thirty* feet thick. A curious manufactory, which produces medallions in *basso-relievo*, is carried on at this place.

570. *Manufacture of medallions.*—The water is first allowed to stand in a cistern, where the sulphate of lime is deposited. It is then conveyed to a chamber, through a tube, from the end of which it falls ten or twelve feet, the current being broken by numerous small sticks crossing each other, and by which means the spray is dispersed around the room. Here are placed the molds of the medallions to be formed, which are first rubbed over with a little soap. The water, striking on these molds, leaves particles of carbonate of lime, which, gradually increasing, leaves exact and beautifully white casts of their figures.

The solid matter left by this spring, is a mass of limestone and gypsum rock, a mile and a quarter long, the third of a mile in breadth, and in some places, at least two hundred and fifty feet in thickness. The length of this deposit terminates abruptly, being crossed by a small

stream, which carries away the undeposited matter with the waters of the spring, otherwise it would have been much more extensive.

571. *Time indicated by this spring.*—The quantity of matter deposited from these springs, shows the newness of the earth, or at least of the present order of things on its surface; for had they existed at the period when Mr. Lyell supposes the cataract of Niagara was at Queenston, and discharged their waters, and formed depositions, as they do at the present day, and which it is certain they did at the time of the Romans, these strata ought to have been at least ten thousand feet thick.

It is apparent, from what has been stated concerning calcareous springs, that in the lapse of ages, considerable changes must have been made in the earth's surface from this source. But it must not be forgotten that this cause is local in its nature, being confined chiefly to volcanic districts; and that even such districts seldom contain springs which work such changes as are above described.

SILICIOUS SPRINGS.

572. *Solution of silex in water.*—Although we possess no chemical process by which water can be made to dissolve pure silex, or flint, yet, in the great laboratory of nature, this effect is produced. There is, however, a process in chemistry, in which, by a previous combination, silex becomes soluble in water, and which, perhaps, affords an analogy to the process employed by nature. If silex be finely pulverized, and then melted with a quantity of common alkali, the whole becomes soluble in hot water. Now, springs containing any considerable quantity of silex, are always of high temperatures; and it is to the great degree of heat which exists at their sources, together with small portions of alkali, which volcanic rocks contain, and which the water dissolves, that we are to attribute the property these waters possess, of holding silex in solution. Springs containing any considerable quantity of silex, are, however, exceedingly rare, and are mentioned here, rather on this account, than for the changes they have produced on the earth's surface.

573. GEYSERS OF ICELAND.—But the Geysers of Iceland afford the most remarkable examples of the deposition of

silex. These springs are situated in a volcanic district, the surface of the ground out of which they rise being covered with streams of ancient lava, through the fissures of which, steam and hot water are emitted in various places.

The great Geyser, which has excited so much interest, on account of the singular phenomena which it exhibits, rises out of a basin at the summit of a circular mound, composed of silicious incrustations, deposited from the spray of its waters. The diameter of this basin, or crater, is fifty-six feet in one direction, and forty-six in the other.

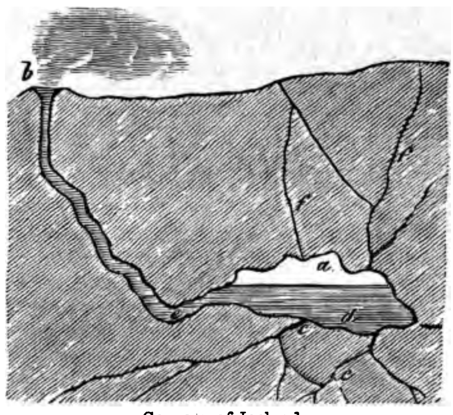
In the centre of this basin, is a natural pipe, seventy-eight feet in perpendicular depth, and from eight to ten feet in diameter, gradually widening as it opens into the basin. The basin, as the spring intermits, is sometimes empty; but is more commonly filled with beautifully transparent boiling-hot water, which is often in a state of violent ebullition. During the rise of the water up the pipe, especially when the ebullition is most violent, subterranean noises are heard, like the distant firing of cannon, and a slight tremor of the earth is felt near the place. The sound then increases, and the motion of the earth becomes more violent, until at length a column of water is thrown up from the pipe, in a perpendicular direction, to the height of from one to two hundred feet, attended with loud explosions. This is continued, with interruptions, like an artificial fountain, for a few minutes; the water at the same time giving off immense quantities of steam and vapor; when the pipe is evacuated by the discharge of its whole contents of water, and there follows an immense column of steam, which rushes up with amazing force, and a loud thundering noise; after which, the eruption, or paroxysm, terminates, and the Geyser becomes quiet.

574. *Stones broken into fragments.*—If stones are thrown into the pipe, or crater, during an eruption, they are instantly ejected; and such is the explosive force of the steam, that masses of hard rock thrown in, are returned into the air, shivered into small fragments. Mr. Henderson, late a resident in Iceland, and well acquainted with these phenomena, states, that by throwing stones into the pipe of the Geyser, he could bring on an eruption in a few minutes, and that, in such cases, the fragments of stone, as well as the water, were thrown much higher than

usual. When an eruption had been brought on in this manner, and the water had been ejected, the steam continued to rush up, with amazing force, attended by a deafening roar, for nearly an hour; but the Geyser, as if exhausted by this effort, did not give symptoms of a fresh eruption when its usual interval had elapsed.

575. *Explanation of these phenomena.*—In the different explanations which have been offered, to account for phenomena so singular and astonishing, and which have been no where else observed, most writers agree in supposing a subterranean cavity, where water and steam collect, and where the free escape of the same is interrupted at intervals, or until it acquires sufficient force to overcome the resistance occasioned by the pressure of the water. This will be readily understood by the annexed diagram, reduced from Mr. Lyell, and we may remark that the theory is the same with that of intermitting springs, only that the Geyser acts by steam, while the other is explained on the principles of the syphon.—*See the Author's Nat. Philosophy.*

LIGN. 109.



Geysers of Iceland.

In explaining this cut, suppose water, percolating from the surface of the earth, or from springs below, finds its way into the subterranean cavity *d*, by the fissures *f f*

while at the same time steam, of an extremely high temperature, emanates from volcanic rocks into the same cavity, through the fissures *c c*. A portion of the steam, in the first place, would be condensed into water; but its temperature continuing to increase by the latent heat of the steam, the lower part of the cavity would soon be filled with the boiling fluid, while the upper part would be filled by steam under considerable pressure. The steam, continuing to form, the water being now too hot to condense it, would soon, by its expansive force, drive the water up the pipe or fissure, *e b*, whatever might be its height, and thus the basin at the surface would be filled, and an eruption take place. When the pressure is thus diminished, the steam in the upper part of the cavity *a*, would expand, or probably a portion of the boiling water, under diminished pressure, would be instantly converted into steam, and the passage being free, would rush up the pipe in the same manner as is seen and heard on opening the safety valve of a steam-boiler. If the pipe be choked up artificially with stones, even for a few minutes, a great increase of heat would be occasioned, since the steam would thus be prevented from escaping; so that the water would be made to boil in a few minutes, and thus an eruption would be brought on, as stated by Mr. Henderson.

This explanation accounts for all the phenomena observed in the Geysers; and although we cannot be certain of its truth, still there is every reason to believe that such a cavity exists, and it is certain that steam is the moving power.—*Lyell's P.* vol. ii. p. 465.

CHAPTER XXXVIII.

DELTAS IN LAKES AND THE SEA.

Considerable changes have taken place by causes now going on, in consequence of the deposition of earthy matter at the mouths of rivers, where they enter lakes or seas. We have already given an account of the accumulation of land along the shores of the Adriatic, in consequence, chiefly, of depositions from the river Po. The quantity of

matter thus carried down by different rivers, of similar magnitudes, differs exceedingly; this difference depending much on the rapidity of the stream, and its liability to overflow its banks at certain seasons.

576. *Delta of the Lake of Geneva.*—The Lake of Geneva is thirty-seven miles long, and from two to nine miles broad. The Rhone enters at one end of this lake, and the city of Geneva stands at the other. The water, where it discharges itself near the city, is exceedingly clear and transparent, but at the upper end it is commonly turbid, in consequence of the matter brought down by the Rhone.

Mr. De la Beche, after numerous soundings, found that the depth of the water, in the middle of the lake, was from one hundred and twenty to one hundred and sixty fathoms; but on approaching the mouth of the Rhone, the water began to grow shallower at the distance of a mile and three-quarters from that end of the lake. It may be stated, therefore, that the strata annually produced by the river are about two miles in length. From soundings, it has been ascertained that, in some places, the deposits from the Rhone are probably from six to nine hundred feet in thickness; and from the remains of some Roman buildings on the border of the lake, Mr. Lyell judges that this accumulation has taken place within the last eight hundred years. "If," says he, "we could obtain the depth of this accumulation, formed in the last eight centuries, we should see a great series of strata, probably from six to nine hundred feet thick, and nearly two miles in length, inclined at a very slight angle."

Mr. Lyell proposes a plan for estimating the time when the Lake of Geneva, or the Leman lake, will become dry land, by the accumulations from the Rhone.

The capacity of the lake being obtained, "it would," says he, "be an interesting subject of inquiry, to determine in what number of years the Leman lake would be converted to dry land. It would not be difficult to obtain the elements for such a calculatlon, so as to approximate at least to the quantity of time required for the accomplishment of this result. The number of cubic feet of water annually discharged by the river into the lake being known, experiments might be made in winter and summer to determine the proportion of matter held in suspension, or in chemical solution, by the Rhone."

Such calculations, however, after all the data that could be obtained, would be exceedingly uncertain; and since the elements proposed by the author have not been obtained, we do not extract his speculations on this subject.

577. *Rate of formation.*—But were it ascertained, exactly, how much alluvial matter is carried down by the Rhone at the present day, still, this would decide nothing definitely with respect to the time during which this accumulation has been forming. According to Mr. Lyell's supposition, above cited, a part of the delta has formed at the rate of about a foot in a year; namely, from six to nine hundred feet in eight hundred years. Now, allowing that the Rhone has, on an average, deposited a foot of matter a year in the lake, and has continued to do so ever since the deluge, then the accumulation ought to be at least four thousand feet thick, which would long ago have filled up the Leman lake, and made it solid ground. The phenomena of this lake, therefore, clearly shows, that either it has not received the Rhone for so many years; or, if so, that its waters contained less solid matter anciently, than at present. In either case, it is quite certain that no argument can be derived from the present condition of this delta, in favor of the high antiquity of the present form of the earth. But, on the contrary, if any conclusions can be drawn from this source, they are in direct coincidence with the idea that the present order of things are of recent origin, and therefore in confirmation of the truth of the sacred history of the deluge.

578. Accumulations in the Baltic.—The question whether the waters of the Baltic sea have been sinking, or whether they have remained stationary, and the land has risen, has been a subject of controversy among philosophers, during more than half a century. Celsius, a Swedish astronomer, long since attempted to prove that the waters of this sea had suffered a depression, at the rate of about 45 inches in a century, from the earliest times. He contended that the proof of this change rested, not only on modern observation, but also on the authority of the ancient geographers, who state that Scandinavia, now a peninsula, was formerly an island. In more modern times, he also claimed that places, which once were sea-ports, were now at considerable distances from the water; and that rocks which were formerly covered by the water,

were now naked, and even some of them were eight feet high, though 150 years ago they were submerged.

579. *Objections to this theory.*—On the contrary, the objectors to Celsius' theory contended that all the facts brought forward to prove the sinking of the water, could be explained and accounted for on other principles. They claimed that accumulations of earth, by the sediment from rivers, or the action of currents, sufficiently explained the reason why some places, once sea-ports, are now at a distance from the water; the land at these localities had extended into the sea, while the level of the water had not changed. And, with respect to the rocks at a distance from the shore, it was shown that this island consisted of sand and drifted stones, and that during great tempests in the winter, not only more sand, but large rocks were thrown upon it by the ice, and there remained. It was thus contended that these rocks had risen, while the water remained stationary.

580. *Action of the Swedish government on this subject.*—This subject being of great interest to the country in the region of the Baltic, the Swedish government directed experiments to be made, by cutting grooves in stationary rocks on a calm day, on the exact level of the water, so that, if possible, this long and exciting controversy might be in a train of accurate decision. In 1820–21, all the marks made before those years were examined by the officers of the pilotage establishment of Sweden; and in their report to the Royal Academy of Stockholm, they declared that, on comparing the level of the sea at the time of their observations, with that indicated by the ancient marks, they found that the water was comparatively lower than formerly, at certain places, but that the amount of change, during equal periods of time, was not the same. During this survey, they cut new marks for the guidance of future observers.

581. *Mr. Lyell's observations in* 1834.—Mr. Lyell states, that fourteen years after the marks of 1821 were cut, he had an opportunity, by a visit to that country, to examine this subject in person, and the following is a summary of his observations:

"In that interval, the land appeared to me to have risen, at certain places north of Stockholm, about five inches. I also convinced myself, during my visit to Stockholm,

after conversing with many civil engineers, pilots, and fishermen. and after examining some of the ancient marks, that the evidence formerly adduced in favor of the change of level, both on the coasts of Sweden and Finland, was full and satisfactory."

582. *Amount of change diminishes towards the south.*—The sinking of the level evidently diminishes as we proceed from the northern parts of the gulf of Bothnia, towards the south, being very slight around Stockholm. Some writers have, indeed, represented the rate of depression, at that city, as very considerable, because certain houses, which are built on piles, have sunk down within the memory of persons still living, so as to be out of perpendicular, and this in consequence of the tops of the piles decaying, and giving way, where they are exposed to the action both of the air and the water.

583. *No tides in the Baltic sea.*—To the inquiry, whether a variation of level in the Baltic, amounting to only a foot or two, can be clearly determined, it is replied, that except near the Cattegat, there are no tides in that sea; and that it is only when particular winds have prevailed for several days in succession, or at certain seasons of the year, when there has been an unusually abundant influx of river water. or when these causes have combined, that the Baltic is made to rise two or three feet above its standard level. The fluctuations due to these causes, are nearly the same from year to year; so that the pilots and fishermen believe, and apparently with reason, that they can mark a deviation, even of a few inches, from the ordinary or mean height of the waters; and by such marks it is proved that the waters have gradually retired.

584. *Has the land risen, or the waters suffered a recession?*—It appears, therefore, that the original theory of Celsius, that the waters of the Baltic have suffered a gradual depression, is no longer doubted; but whether from the rising of the land, or the retiring of the sea, is the next question. That the former has been the case, there can be no doubt; since unconfined water will, in all cases, seek its own level; the Baltic, therefore, having an outlet into the ocean, could suffer no permanent depression without a general diminution of the waters of the former. The retiring of its waters, consequently, is a sufficient proof of the rising of the land.

585. *To what extent, in northern Europe, has the land risen?*—It seems probable, from the facts and observations stated, that this gradual upward motion of the earth extends from Gottenburg, to Torneo, and from thence to the North Cape, the rate of elevation always increasing towards the north. The two extremities of this line, are more than a thousand geographical miles distant from each other; and as both terminate in the ocean, we know not how much further the same effect has been produced under the water. As to the breadth of this elevated tract, there is little certainty, though it probably extends to considerable distances on each side of the gulf of Bothnia, and perhaps far into the interior both of Sweden and Finland.

586. *How long has this elevation been going on?*—It appears that this elevation of the land commenced at a very early period; for, from the evidence of marine shells, which are found in Norway, to the height of 400 feet above the present level of the Baltic; and at Uddevalla, several hundred miles to the south, at the elevation of 200 feet, above the same level, it seems to be proved that all this region of country was once covered by the sea, and consequently, that this gradual rising has now amounted to at least from 200 to 400 feet. Now, by calculations made on data, furnished by the recession of the water from buildings, and, more recently, by marks made in mural rocks along the shores, it appears that the elevation has been at the rate of about four feet in a century, which 4 feet, multiplied by 5,000 years, is equal to 200 feet. It would seem, therefore, from these calculations, that at the present estimated rate, the elevation began at least 5,000 years from the present time. But it is quite obvious, that little reliance, with respect to time, can be made on these estimates; since, for aught that can now be known, the rising, anciently, might have been much more rapid than at present; and even the principal elevation might have been in a single hour.—*Lyell*, vol. ii. p. 404.

587. *Cause of this elevation.*—In no instance has a similar phenomenon been known to geologists. Local elevations of the land, as well as the sinking of certain confined tracts, have often taken place, as we have already shown under the head "Earthquakes." But a gradual rising of the earth, embracing whole kingdoms, and that so slowly

as for centuries to be unknown to its inhabitants, and that too in a region where volcanoes do not exist, and where even earthquakes are unknown, is a wonder in geology, not easily explained. In the present state of knowledge, this phenomenon can only be attributed to some change in the state of that mass of igneous matter, which undoubtedly exists every where under the crust of the earth.

588. *Delta of the Rhone in the sea.*—We have seen that the Rhone deposits large quantities of sediment in the lake of Geneva, and have noticed with what crystaline transparency the waters of that lake are discharged to continue the same river towards the sea. But, says Mr. Lyell, "scarcely has the river passed out of the Leman lake, before its pure waters are again filled with sand and sediment by the impetuous Arve, descending from the highest Alps, and bearing along in its current the granitic detritus [broken rocks] annually carried down by the glaciers of Mont Blanc." The Rhone, also, afterwards receives vast contributions of transported matter from the Alps of Dauphiny, and the primary and volcanic mountains of central France, so that when it reaches the Mediterranean, it discolors the waters of the sea to the distance of many leagues.

The advance of the delta of the Rhone into the sea, is proved by many circumstances, and particularly by the facts that an island described by Pomponius Mela, an ancient Latin geographer, is now far inland, and that a location which was a harbor in 898, is now three miles from the shore. It is also known that Psamodi, which was an island in 815, is at the present time six miles from the sea.

As the Rhone enters the sea by several mouths, at considerable distances from each other, a large tract of country is brought within its influence; and thus, besides extending the land along the shore, marshes of great extent have, during the lapse of ages, been filled up by its annual deposits.

589. *Solid rock from carbonate of lime.*—In the course of this river it receives the waters of a vast number of springs containing carbonate of lime in solution, and which, mixing with the waters of the Rhone, is not deposited until it reaches the sea. Hence, the delta of this river, instead of consisting of loose incoherent sediment, like the depos-

its from most other rivers, consists chiefly of *solid rock* the carbonate of lime acting as a cement to the sediment, when this exists, or, in its absence, forming limestone, nearly pure. This is a well-ascertained fact; for large masses of this rock are quarried for various purposes, and are found to consist of sand consolidated by a calcareous cement, and mixed with broken shells. After the sand has been deposited, the waters still hold a portion of the carbonate in solution, which is thrown down in a purer state, and even sometimes in the form of crystaline masses. As an example, there exists a cannon in the museum of Montpelier, taken up from near the mouth of this river, imbedded in *crystaline limestone.*

Thus, we see that solid limestone is now constantly forming, in which are imbedded shells, as in the ancient marbles, which some geologists have contended were thousands of years older than the creation, according to Moses. This circumstance is important, and will be adverted to in another place.

590. *Marine and fresh-water shells.*—In a late survey of the coast of the Mediterranean, the ships employed at the mouth of the Rhone were obliged to quit their moorings when the wind blew strongly from the south-west. Captain Smith, one of the officers on this service, states, that when the ships returned after such a wind, the new sand-banks in the delta were covered with a great abundance of marine shells, which were swept there by the current caused by the wind. The circumstance appears to explain phenomena of some importance in geology. In some ancient strata it has been claimed that marine and fresh-water shells alternate with each other, and hence it has been supposed that, at least in such places, the sea had retired for a time, while fresh water occupied its place; after which, the sea again resumed its former bed; and so alternately, as often as the different kinds of shells were repeated. But it appears, from the above statement, that the explanation of such appearances is very simple, and that it is unnecessary to believe that the ordinary course of nature was changed, in order to produce such effects: for, at the mouth of the Rhone, a strong south-west wind only is required, to occasionally mix the shells of the sea with those which are brought down by the fresh water, or which live in its current.

591. *Delta of the Ganges.*—The Ganges and the Burrampooter descend from Himmalaya mountains, the most lofty on the globe. The latter river may be considered as a branch of the former, and falls into it long before their united waters reach the sea. The Ganges is discharged into the bay of Bengal, which forms a vast indenture into the continent, of more than two hundred miles in length. The delta of the Ganges commences more than 200 miles from the bay of Bengal, in a direct line, and 300, if the distance be estimated along the windings of the river. That part of the delta which borders on the sea, is divided by a vast number of rivers, or creeks, all of which are salt, except those which communicate with the principal arms of the Ganges. This tract is famous under the name of *Sunderbunds*, being the common haunt of tigers and alligators. Its extent, according to the account of Major Rennell, is equal to the whole principality of Wales. Its base, bordering on the sea, is about two hundred miles in length, and, on each side, it is inclosed by an arm of the Ganges. Besides these, through which the water of this immense river is now discharged, there are six other great openings through the delta into the sea, each of which has evidently, at some ancient period, been the principal bed of the river. During the period of overflow, the greater part of this vast delta is covered with the water of the river, so that the Ganges appears to be flowing into a vast lake, instead of itself inundating and sweeping a whole territory of India. So great is the quantity of mud and sand carried down by this immense current, at such seasons, and so vast the quantity of water it discharges, that the ocean is discolored by it to the distance of sixty miles from its mouth.

592. *Islands formed and destroyed.*—In various parts of this delta great accumulations, or islands, are formed in the course of a few years, and perhaps as soon swept away, and similar ones formed in other places. Some of these, which are islands during freshets, Major Rennell states, are equal in extent to the Isle of Wight, and thickly inhabited. The people are, however, always in danger of being swept away by floods of uncommon height. In 1763 such an inundation happened, the water rising six feet above ordinary floods; and consequently the inhabitants of one of these districts, of considerable extent, were,

with their horses and cattle, totally ingulfed, and perished in the water.

These examples of the effects of running water, in changing the surface of the globe, are sufficient for the purposes intended. In all parts of the world, such effects are constantly taking place, to a greater or less extent.

The aggregate accumulation of solid ground, by the formation and extension of deltas on the surface of the whole earth, must be very considerable during every year; and yet these effects are hardly appreciable in relation to the changes they produce on the entire surface of the globe. It is true, that the course of navigation is in a few instances obstructed, or changed, by these accumulations; but in general the same sea-ports, of which the earliest records of history give any account, are still accessible.

593. *These accumulations of recent origin.*—Had these accumulations commenced at very remote periods, as some have contended, and continued to the present time, it is quite certain that many lakes now existing would have become dry land, and that the deltas of rivers falling into the sea, would have been far more extensive than we find they are. All the facts, therefore, which are connected with the effects of rivers in the formation of dry land, tend to show that the present form of the earth has not existed more than a few thousand years, and that it has suffered no considerable changes from running streams, as one of the causes now in operation.

QUANTITY OF SEDIMENT IN RIVER WATER.

594. Having in the preceding pages given such an account of the effects of rivers in forming solid depositions, as our limits will allow, it is proper here to present the geological student with an account of the estimates and experiments, which have been made, to ascertain the quantity of solid matter water is capable of holding in suspension.

It is proper, however, that we should also state, that few, if any of these estimates, can be considered as more than approximations to the truth; still they are such as are quoted by the best writers, and are probably as accurate as any in existence at the present day. Major Rennell states that a glass of water, taken out of the Ganges during the height of its annual flood, yields about one part in

four of mud. "No wonder, then," says he, "that the subsiding waters should quickly form a stratum of earth, or that its delta should encroach upon the sea." The same writer, who resided many years in the vicinity of the Ganges, computed with great care the quantity of water which that river discharges into the sea, and which by his estimate amounted, during a year, on an average, to *eighty thousand cubic feet for every second of time.* When the river is at its greatest height, during its annual inundation, and consequently its motion much accelerated, the quantity discharged per second, by the same estimate, was *four hundred and five thousand cubic feet.*

595. *Quantity of solid matter in the Ganges.*—Mr. Lyell has made a computation of the quantity of solid matter carried down by the Ganges, taking as his data the experiment of Major Rennell, and his estimate of the quantity of water it discharges. "If it were true," says he, "that the Ganges in the flood season contained one part in four of mud, we should then be obliged to suppose that there passes down every four days a quantity of mud equal in volume to the water which is discharged in the course of a day, or twenty-four hours. If the mud be assumed to be equal to one half the specific gravity of granite, (it however is more,) the weight of matter daily carried down in the flood season would be about sixty times the weight of the great pyramid of Egypt. If the Ganges discharges 405,000 cubic feet of water per second, which was the estimate of Major Rennell, then, in round numbers the quantity of mud discharged per second, would be 100,000 cubic feet, which being multiplied by 86,400, the number of seconds in 24 hours, would give 8,640,000,000 cubic feet of mud going down the Ganges per day. The weight of this (allowing as above) would be equal to that of 4,320,000,000 cubic feet of granite. Now, about twelve and a half cubic feet of granite weigh a ton, but throwing out the half, the matter discharged by the Ganges every day is 360,000,000 of tons. This is sixty times the weight of the great pyramid of Egypt, which, if solid, is computed to weigh 6,000,000 of tons."

596. *Quantity of sediment in the Yellow river.*—But although the Ganges may be supposed to transport a much greater quantity of mud, even according to its size, than any other river, still there can be little doubt but Major

Rennell very far over-rated the quantity of solid matter its waters contained. The Rhine, when most flooded, has been computed to contain one part of mud in a hundred of water; and Sir George Staunton, by several observations, calculated that the water of Yellow river, in China, contained earthy matter in the proportion of one part to two hundred. In this proportion he estimated that the waters of that river brought down 48,000,000 of cubic feet of solid matter daily.

597. *Average quantity of sediment.*—According to the calculations of Manfredi, the celebrated Italian hydrographer, the average amount of sediment, in all the running streams on the globe, is one part in 175. From such data, he estimates that it would take a thousand years to raise the general bed of the sea a single foot, provided none of this sediment was thrown back again upon the shores.

From what has been stated, the reader will observe that, although a considerable number of experiments have been made on this difficult subject, there remains much more to be done, before satisfactory results can be offered. It is, however, certain, that great quantities of solid matter are transported by running streams; and, with respect to lakes and ponds, there can be no doubt but they are gradually filling up; and that, if the same causes continue which we have described, all these bodies of water will finally be replaced by dry land.

But there can be no possible estimate made of the time required for such an event, since the quantity of solid matter which streams transport, must be constantly decreasing, in proportion as lakes and ponds approach the level of the country in which they are. In a flat country, therefore, a lake may remain for centuries without any appreciable elevation of its bottom.

The great depth of some lakes at the present day, when these circumstances are considered, is a good proof of the newness of the present order of things on the earth, and consequently of the truth of the Mosaic history of its creation.

598. *The level of the sea has not changed.*—With respect to the level of the sea, it has been shown that no change has taken place in the Baltic, and we may also state at this place, that it will be seen hereafter, that the remains of Roman buildings show that the Mediterranean sea has

not changed its level for the last 2,000 years. We may therefore, conclude, that either the quantity of matter carried into the sea, has made no appreciable difference with its general level, or that as much solid matter is thrown on the land at one place, as is carried into it in another.

CHAPTER XXXIX.

DESTROYING EFFECTS OF THE SEA.

599. *Large rocks moved by the waves.*—MR. LYELL has adduced many instances of the power of sea-waves to move large masses of solid rock. In the Shetland isles, this effect has been quite surprising. In 1818, during a storm, a mass of granite, 9 feet by 6, was thrown by the waves up a declivity, to the distance of 150 feet; and, in the winter of 1802, a mass of rock, 8 feet by 7, and 5 feet thick, was moved to the distance of 90 feet, by the same force.

The reader, who remembers the immense power which velocity gives a sea-wave, as above illustrated, will be at no loss to comprehend why the strongest ships are sometimes reduced to fragments in a few minutes; nor will he wonder at the destroying effects which a wide ocean must produce on a coast, which is not guarded by a strong barrier of solid rocks.

600. *Destruction of the village of Mathers.*—The village of Mathers, on the east coast of Scotland, was destroyed by an inroad of the sea, in 1795. This town was guarded by a barrier of limestone rock next the shore; but during a storm, the waves of the ocean broke through this barrier, and in one night destroyed and swept away the whole village. The sea penetrated 150 yards inland, where it has maintained its ground ever since.

601. *Eastern coasts of England.*—The eastern coasts of England are constantly suffering from the inroads of the sea. On the old maps of Yorkshire, many spots are marked as the sites of towns, which are now sand-banks in the ocean. A greater or less portion of the coasts of

Norfolk and Suffolk, are every year swallowed up by the sea. The town of Sherringham, on this coast, exhibits a melancholy proof of this fact. With respect to this town, Mr. Lyell states, that at one point there is now a depth of water, of 25 feet, (sufficient to float a frigate,) where, only 48 years ago, there stood a cliff, 50 feet high, with houses upon it. Further to the south, are cliffs more than 200 feet high, more or less of which are every year precipitated into the ocean, in consequence of being undermined by the waves. The whole site of the ancient town of Cromer, now forms a part of the bed of the German ocean, the inhabitants having gradually pulled down their houses, and removed inland, as the sea encroached upon them; and, from their present situation, they are in danger of being dislodged by the same cause. From this neighborhood, in the year 1822, a mass of earth and rocks was precipitated into the sea, to the extent of twelve acres, the cliffs being 250 feet high; and on the same coast, three ancient villages, several manors, and large portions of a number of parishes, have, from the same cause, gradually disappeared, and been replaced by the ocean.

Since the time of Edward the Confessor, as appears by the records, the sea-coast town of Dunwich, has lost, in succession, a monastery at one time; at another, several churches; at another, 400 houses; and, subsequently, another church; the town hall and jail, together with many other buildings, all precipitated into the sea.

These are given as specimens of the devastating effects of the sea in different parts of the world, and by which, it appears, that if, on the one hand, large tracts of coast are forming, and encroaching upon the ocean in one part of the world, as on the coasts of Italy, so, on the other hand, the sea is encroaching on the land in other parts, probably to an equal extent.

602. *On the coast of Holland.*—In many instances, inundations from the sea have been the means of effecting not only great changes in the surface of the earth, in a short period of time, but also of destroying vast numbers of human beings. On the coast of Holland, these disasters have been peculiarly destructive, as well as on the coast opposite.

A considerable peninsula, which lay between Groningen and East Friesland, and was thickly inhabited, was partly

overwhelmed in 1277, and a considerable portion of the land carried away, with many houses and inhabitants. During the fifteenth century, other portions were destroyed by the same cause, and a part of the town of Forum, a place of considerable size, was swept away. In 1507, not only the remainder of Forum was ingulfed, in spite of the erection of dams, but also several market-towns, villages and monasteries, were entirely destroyed, together with their inhabitants.

603. *Formation of Northstrand*—Further to the north, anciently, lay the district of North Friesland. This was a peninsula; but in 1240, the sea destroyed the land next the coast, and thus formed an island, called Northstrand. This island was originally of considerable extent, but the sea, from time to time, swept away small portions of it, until the inhabitants became so concentrated, that when the island was only four geographical miles in circumference, their number was still 9,000. At last, on the night of the 11th of October, 1634, a flood from the sea swept over the whole island, and destroyed at once a great proportion of the inhabitants, all the houses, churches and cattle, carrying away even the land that had sustained them. By this dreadful calamity, there was swept away 1,300 houses, with all the churches, 50,000 head of cattle, and more than 6,000 people.

We might continue these accounts, with regard to the changes which have taken place on the same coasts, to great length; but our design being chiefly to give examples, rather than general details, we will here conclude this part of our subject.

CHAPTER XL.

FORMATION OF CORAL ISLANDS.

604. It is but recently that any observations, tending to interest or inform the naturalist, have been made on the production of the *Coral islands*. But the great extent to which these islands have been formed, together with the rapidity

with which it is said they are increasing, gives the subject a high degree of interest, not only in respect to the geological changes thus produced, but also with regard to the interests of commerce, which these changes are producing. For it is said that many straits and seas, especially in the Pacific ocean, which were formerly, and in the memory of man, safe for the passage of the largest ships, have now become dangerous, or even impassable, for vessels of a moderate size.

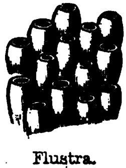
605. *Coral polypi, or animalcules*—In a popular view, the coral may be considered a calcareous structure, inhabited by numerous small animals, or polypi, each coraline form possessing, or having been constructed by, its own peculiar species.

These animalcules form the order *Coraliferi*, of the class POLYPI, in *Cuvier's Animal Kingdom.* They are a singular and very curious tribe of beings, many of which are too minute to be seen without the microscope.

The Coraliferi constitute that numerous suite of species which were formerly considered as marine plants; and of which the individuals are, in fact, united in great numbers to constitute compound animals, mostly fixed like plants, either forming a stem, or simple expansion, by means of a solid internal substance. The individual animals are all connected by a common body, and are nourished in common, so that what is eaten by one, goes to the nourishment of the general body of all the other polypi.—*Cuvier*

LIGN. 110.

Fig. 1.



Flustra.

Fig. 2.

Coral polypi.

606. *Organization of the polypi.*—If we examine the little patches of white calcareous matter, called *flustra*, that may be seen on every sea-weed or shell, picked up on

the sea-shore, by means of a microscope, we shall find that these mere specks, now appearing like delicate lace-work, are, in truth, members of the animal kingdom. This flustra will be found full of little elevated pores, *Lign*. 110, *Fig*. 1, each containing one or more animals, which, while under the water, will protrude many tentacula, or feelers, having motion in all directions, *Fig*. 2. These animals belong to the same tribe, and are, in fact, members of the same family with the numerous species, by whose secretory powers, vast mountains of calcareous matter, in the forms of corals, are produced.

The substances called *corals*, are animal secretions, formed by the action of minute vessels, like the bones, hoofs, and nails of mammiferous animals, and without the design or knowledge of the polypi. (*See* p. 91.)

There are a great number of species belonging to this family, differing in size and form, all of them small, but some of them sufficiently large to be seen and examined by the naked eye.

607. Red Coral, (*Corallium rubrum.*)—This is a different genus from those which form the coarse white kinds. The red coral is a branched zoophyte, somewhat resembling, in miniature, a tree deprived of its leaves and twigs. It seldom exceeds one foot in height, and is attached to the rocks by a broad expansion. It consists of a brilliant red, stony axis, invested with a fleshy, or gelatinous substance, of a pale blue color, which is studded over with stellate polypi. This species, it is well known, is so dense and compact, as to bear a high polish, and when prepared, is highly esteemed as a female ornament. It is obtained by dredging, in different parts of the Mediterranean and the Eastern seas. It varies much in the hue of its colors, according to its depth in the sea; in shallow water, it is of a deep and beautiful red, a free admission of light appearing necessary to produce the deepest tinge. It is of slow growth, eight or ten years being necessary for it to reach full maturity. It then ceases to grow, and is soon attacked by insects, which pierce it in all directions; when it becomes detached from the rock, and is thrown on shore, where it soon fades, and is reduced to fragments.

608. *Appearance of living corals.*—In some oceans, near the shore, the eye perceives nothing but a bright sandy plain at the bottom, extending perhaps hundreds of miles.

But in the Red sea, the whole bed of this extensive basin of water, is absolutely a forest of submarine plants and corals. Here are sponges, gorgonias, madrepores, and other polyparia, with flags, fuci, and other marine vegetation, covering every part of the bottom, and presenting the spectacle of a submarine garden, of exquisite verdure, enamelled with animal forms, resembling, and even surpassing, in splendid and gorgeous coloring, the most celebrated parterres of the East.—*Wonders of Geology.*

Ehrenberg, the German naturalist, whose labors have so greatly advanced our knowledge of the infusoria, was so struck with the magnificent spectacle presented by the living corals in this sea, that he exclaimed with enthusiasm, "Where is the paradise of flowers that can rival the living wonders of the ocean!"

609. *Coral reef of Loo Choo.*—Capt. Basil Hall gives the following graphic description of a coral reef near the island of Loo Choo, on the coast of China:

"When the tide has left the rock for some time dry, it appears to be a compact mass, exceedingly hard and ragged; but as the water rises, and the waves begin to wash over it, the polypi protrude themselves from holes, which were before invisible. The animals are of a great variety of shapes and sizes, and in such prodigious numbers, that in a short time the whole surface of the rock appears to be alive, and in motion. The most common form is that of a star, with arms, or tentacula, which are moved about with a rapid motion, in all directions, probably to catch food. Others are so sluggish, that they may be mistaken for pieces of the rock, and are generally of a dark color. Where the coral is broken about high-water mark, it is a solid, hard stone; but if any part of it be detached at a spot which the tide reaches every day, it is found to be full of polypi, of different lengths and colors; some being as fine as a thread, sometimes of a bright yellow, and then again of a blue color. The growth of the coral appears to cease when the worm is no longer washed by the sea. Thus, a reef rises in the form of a cauliflower, till the top has gained the level of the highest tides, above which the animalcules have no power to advance, and the reef, of course, no longer extends upwards."

610. FORMATION OF CORAL ISLANDS.—From the navigators Kotzebue, Flindens, M M. Quoi, and Gaimard, who

have each written an account of those islands in the Pacific ocean, the following summary has been made:

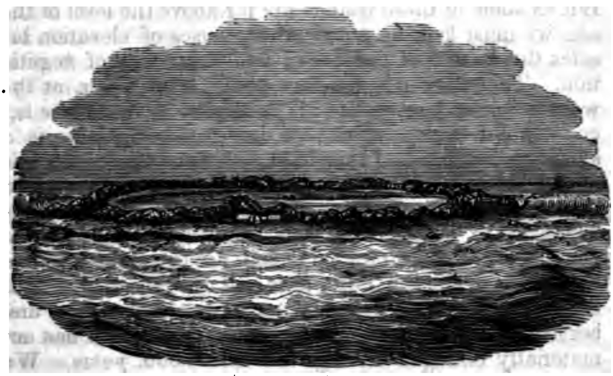
The coral banks are every where seen, in different stages of progress; some are become islands, but are not yet habitable; others are above high-water mark, but destitute of vegetation; while many are overflowed with every returning tide. When the polypi of the corals at the bottom of the ocean cease to live, their skeletons still adhere to each other; and the interstices being gradually filled up with sand and broken pieces of corals and shells, washed in by the sea, a mass of rock is at length formed. Future races of these animalcules spread out, and extend the solid matter on all sides, having, in their turn, increased and elevated this wonderful monument of their existence.

611. *Reefs usually of a circular form.*—The reefs which have been raised above the level of the sea, are always observed to be of a circular, or oval form, often surrounded by a deep, and sometimes an unfathomable ocean. In the center of each of these, is generally a shallow lagoon, or basin, the rim of which being above the waves, the water within is still; and in this, it is said, the smaller and more delicate species of polypi, find a tranquil abode, and there continue their work; while the stronger tribes live on the outer margin of the rim, where the waves dash over them. When the reef is dry, at low water, the animals cease to increase; and there is seen a mass of solid stone, composed of shells, echini, and sand, with fragments of coral, cemented together by calcareous matter, forming a durable barrier against the fury of the waves. Fragments of coral rocks are then thrown up by the water, which, when dry, fall in pieces by the heat of the sun, and remain on the reef in the form of sand. The island is now above the reach of the water, except during storms, when the waves are uncommonly high; and at such times, there is usually an increase of the elevation, by the deposition of coarse materials.

612. *Growth of vegetables on the island.*—The island thus formed, being above the water, is now supposed to be undisturbed by its waves, and offers to the seeds of the cocoanut, and other tropical plants, floating on the water, a soil, in which they take root, and rapidly increase. These, as they decay, together with sea-weeds, and perhaps floating trees cast upon the island, form a vegetable

soil, which is constantly increasing by the decay of its own products; and thus, in process of time, a residence is formed both for man and beast.

LIGN. 111.



Coral island.

Such an island, with its lagoon in the centre, surrounded by trees, is represented by *Lign.* 111.

In this manner, to all appearance, the Polynesian Archipelago has been formed. The foundations of the islands are probably the cones, or craters, of submarine volcanoes.

613. *Extent of coral reefs.*—The grand scale on which these minute beings are effecting changes in various parts of the world, may be imagined from the facts stated by navigators, that in the Indian ocean, to the north of Malabar, there is a chain of coral reefs, nearly 500 geographical miles in length; on the coast of New Holland, is an unbroken line of the same, nearly 400 miles long; and that between this and New Guinea, another coral formation exists, 700 miles in extent. Besides these, the Disappointment island, and Duff's group, are connected by coral reefs, 600 miles long, and over which the natives can travel from one island to the other.

614. *Elevation of coral islands.*—Many of these islands are only a few feet above high-water mark; but it is apparent that the mode of formation, already described

would require long periods of time, to elevate them to any considerable height. Indeed, it is hardly probable that parts near the shores would ever acquire any additional elevation by ordinary means, since occasional high tides would carry away the vegetable matter deposited there. But as some of these islands are far above the level of the sea, we must look for some other causes of elevation besides the waters of the ocean and the decay of vegetation. Tongabatoo is ten feet above high water, at the water's edge; and even this is higher than can be accounted for, from the causes described. But this is a slight elevation, when compared with some others; for one of the Tonga islands, though entirely formed of coral, is, in some parts, more than 300 feet high. It is hardly necessary to remark that this elevation cannot be accounted for by the formation of soil, nor the sinking of the ocean; since, in the latter case, all the other islands in the vicinity, would be found at a similar height; and besides, it is well known that the level of the sea has not materially changed during the last 2,000 years. We must, therefore, attribute the elevation of these islands to volcanic causes, acting beneath them. One of these islands, indeed, contains a volcano always in action.

PART VI.

GEOLOGICAL MISCELLANY

CHAPTER XLI.

THE DELUGE.

615. *Epoch of the Deluge.*—THE period of the general deluge, the circumstances of which are contained in the sacred Scriptures, is fixed by chronological writers at the year 1656 after the creation, corresponding to the year 2,348 before the Christian era. These two make the period of the creation, 4,004 years B. C. According to *Blair's Chronology*, on the 10th day of the second month, which was on Sunday, Nov. 30th, B. C. 2,347, God commanded Noah and his family to enter the ark; and on the next Sunday, Dec. 7th, it began to rain, and continued to rain 40 days; after which, the deluge prevailed 110 days, making its continuance 150 days from the beginning. On Wednesday, May 6, 2,348 B. C., the ark rested on Mount Ararat. The tops of the mountains became visible on Sunday, July 19th, and on Friday, Nov. 18th, Noah, and all they that were with him, went forth from the ark.

Without reference to the sacred Scriptures, we never could have known the *time* when this great flood happened, though the fact itself is still capable of the strongest proof, from the geological indications existing on the earth's surface.

616. *Cuvier's opinion.*—Baron Cuvier, after having spent a great portion of a long life in investigating the natural history of the globe, and its geological phenomena, comes to the following conclusions on the subject of the universal deluge: "I concur," says he, "with the opinions of M. M. De Luc and Dolimieu, that, if there be any thing determined in geology, it is, that the surface of our globe has been subject to a vast and sudden revolution, not longer ago than five or six thousand years; that this revolution

has buried, and caused to disappear, the country formerly inhabited by man, and the species of animals now most known; that, on the contrary, it has left the bottom of the former sea dry, and has formed on it the countries now inhabited; that since this revolution, those few individuals whom it spared, have propagated, and spread over the lands newly left dry; and consequently, it is only since this epoch, that our societies have assumed a progressive march; have formed establishments, raised monuments, and combined scientific systems."—*Rev. Globe*, 180.

617. *Present indication of the Deluge.*—The effects of this grand cataclysm are still to be traced in every country, and in nearly every district, to this day. Vast accumulations of rounded, or water-worn pebbles, huge blocks of granite, and immense beds of sand and gravel, are found in places where no causes, now in operation, or any which have happened since the era of profane history, could have placed them; and still, that these materials have been moved, is evident from the circumstances, or the places where they are now found.

618. *Dr. Buckland's opinion.*—"In the whole course of my geological travels," says Rev. Dr. Buckland, "from Cornwall to Caithness, from Calais to the Carpathians; in Ireland, in Italy, I have scarcely ever gone a mile without finding a perpetual succession of deposits of gravel, sand, or loam, in situations that cannot be referred to the action of modern torrents, rivers, or lakes, or any other existing causes. And with respect to the still more striking diluvial phenomena of drifted masses of rock, the greater part of the northern hemisphere, from Moscow to the Mississippi, is described by various geological travelers, as strewed on its hills, as well as its valleys, with blocks of granite, and other rocks of enormous magnitude, which have been drifted, mostly in the direction from *north* to *south*, a distance, sometimes, of many hundred miles from their native beds, across mountains, valleys, lakes, and seas, by a force of water, which must have possessed a velocity to which nothing that occurs in the actual state of the globe, affords the slightest parallel."

How it is known that rocks have been transported.—If it be inquired, how it can be ascertained that blocks of granite, or other boulders, have been transported from a distance, and that they do not belong to disrupted moun

tains in the vicinity of the places where they are found, it is answered that there is a peculiarity in the texture, color, or appearance of the rocks composing every formation, or range of mountains, by which the eye of an experienced mineralogist can distinguish one from the other. As examples, the calcareous rock of Gibraltar, and the iron ore of Elba, specimens of which are in every collection, are readily known, even by the most common observer, from all other minerals. With the eye of the mineralogist, and the analysis of the chemist, therefore, no difficulty occurs in identifying, with certainty, any specimen, with the rock to which it belonged.

619. *Glacial Theory.*—It is, however, proper to state here, in respect to the transportation of rocks, across "valleys, lakes, and seas," as above described by Dr. Buckland, that since that was written, geology has made great advances, and that the theory of the glaciers will much more satisfactorily account for the transfer of boulders across valleys, in some situations, than the former diluvial theory. The glacial theory, however, does not at all interfere with the diluvial, in accounting for the mounds of sand, stones, and earth accumulated in level countries. Those spoon-shaped hills, composed of sand and gravel, and rising to the height of 50 or 100 feet, with valleys between them, running nearly north and south, as seen in various parts of our country, and especially in Massachusetts and Connecticut, are most clearly the effects of an ancient current of water, running from the north-east towards the south-west. Whoever will notice the perfect conformity of such gentle hills, or mounds and valleys, as they occur almost every where between the higher lands and plains made by rivers in New-England, cannot but be struck with the truth of the diluvial theory; for, on no other supposition than that of a vast body of water, passing with great velocity over the country, can these appearances be accounted for.

620. *The glacial, or ice theory, will not account for such appearances.*—The glacial theory (to be explained) accounts very satisfactorily for accumulations of angular rocks existing in valleys, especially in the neighborhood of high mountains, forming what are termed *moraines.* These accumulations, it is true, often contain sand and gravel, with the fragments of rocks; but elevations formed

by such materials, differ entirely, in appearance, from the smooth, rounded, spoon-like forms which are attributable to diluvial causes.

621. *Power of water to transport rocks.*—In estimating the power of water to transport solid matter, it must not be forgotten that a solid, when immersed in a fluid, becomes lighter by the weight of the fluid which it displaces, and that the solid displaces its own bulk of the fluid.—(*See* 552.)

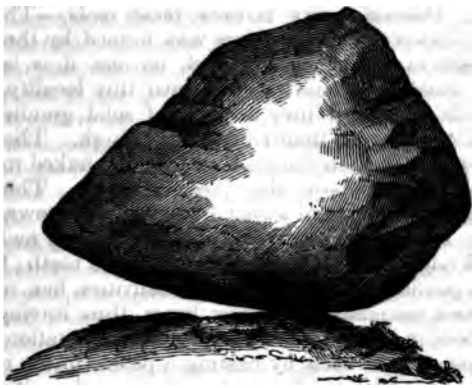
622. *De la Beche on Diluvial action.*—Mr. De la Beche, in his "Geological Manual," under the head of *Erratic Block Group*, remarks: "that the form of the valleys in Plymouth are gentle and rounded, and such as no complication of meteoric causes, that ingenuity can imagine, seems capable of producing; that numerous valleys occur on the line of the faults; and that the detritus (broken rocks) is dispersed in a way that cannot be accounted for by the present action of mere atmospheric waters. I will more particularly remark, that on great Haldon hill, about 900 feet above the sea, pieces of rock, which must have been derived from levels not greater than 700 or 800 feet, and even less, occur in the superficial gravel. They certainly are rare, but may be discovered by diligent search. I there found pieces of red sandstone, porphyry, and a compact silicious rock, not uncommon in the graywake of the vicinity, where all the rocks occur at a lower level than the summit of Haldon hill, and where certainly they could not have been carried by rains, or rivers, unless the latter be supposed to delight in running up hill."

623. *Similar phenomena occur in this country.*—In this country similar phenomena, almost every where, present themselves to the eye of the geologist. Beds of pebbles and stones, of various sizes, including boulders weighing many tons, with their angles slightly abraded, all of them evidently transported, often from places unknown, are found partly buried in the earth, in places where no causes now in operation could possibly have placed them. Such evidences of an ancient flood, are to be seen in nearly every part of our country, and especially in the Eastern states.

624. *Boulders in East Lyme.*—In some instances, these transported blocks of granite are of great size. In East Lyme, Ct., near the road leading from New London to Saybrook, at a location called Keeney's hill, there is a

huge boulder of granite, weighing nearly 400 tons. Any person, after a moment's reflection, would conclude that this rock must have been transported from some other place; for its present situation is on an open field, near the summit of a considerable hill, there being no other rocks, of any kind, on the surface in the vicinity. On examining the neighborhood, however, the inquirer will soon find that it came from a granite hill, of small elevation, situated at the north-east of its present position, at the distance of about two miles, where other rocks remain, of the same texture and appearance.

LIGN. 112.



Rocking-stone at East Lyme.

625. *Rocking-stone at East Lyme.*—On the opposite hill, a mile from this boulder, lies another, perched on the highest summit of a granitic crest, and serving as a landmark, for many miles, in all directions. This is within 100 rods of tide-water, and several of its fellows appear to have fallen down the side of the steep hill, in that direction. This is, also, of granite; and, resting only on a few inches of its base, on a rounded granitic foundation, it requires no great force to set it in motion. Its weight is between 30 and 40 tons, and its form and appearance is represented by *Lign.* 112.

626. *Inferences.*—In the above instances, which are only cited as examples of hundreds of others of the same

character, to be found almost every where, in uneven districts of country, no ingenuity, we think, can suggest the means by which they were moved to their present situations, except that of an overwhelming, deep, and rapid current of water; and, as indicated by the largest boulder, this stream must have run from the north-east towards the south-west. The theory that they were transported by a glacier, can have no foundation in truth; since this would involve the supposition, that a mountain, higher than the place where the erratic rocks are found, is somewhere in the neighborhood; while, in the present case, these rocks are situated, one of them, at least, on the most elevated hills in the vicinity.

627. *Diluvial valley between these rocks.*—That the valley between these boulders was formed by the action of water, at some remote period, no one, it is believed, could doubt, after having examined this locality. The two hills on which they rest, are of solid granite, about one mile apart, and from 75 to 100 feet high. The crests of these have been denuded, leaving the naked rocks, at various points, above the present earth. The earth appears to have been swept from the north towards the south; but being interrupted by the projecting rocks, has formed ridges, or gentle slopes towards the north; but the water, pouring over the southern declivities, has removed the loose materials from their bases, thus leaving steep precipices in that direction. A miniature imitation of this principle may be seen, by casting a pebble into a running stream, and stirring the sand above it, when it will be found that a hill will be formed above the pebble, extending up stream, and ending even with the upper surface of the stone, while below it, there will remain a little precipice down to the base of the pebble, the water having carried away the sand in that direction. If two pebbles be thrown in, two little hills, with mural precipices, and a valley between them, will be the result.

But, to return to the case we have thus attempted to illustrate: the valley between the two hills contains no granitic barrier, by which the moving sand and rocks were interrupted, as the water containing them moved along, and thus the loose materials were scooped out, and transported into the sea, which is not far distant. This is only

offered as an illustration, or example of phenomena, to be seen almost every where.

628. *Inferences.*—Now, as all geologists agree that the present surface of the earth has been greatly, and very materially changed, by the influence of water, at some unknown, and apparently remote period; and as the Mosaic history furnishes us with a circumstantial account of a general deluge, which probably swept over a large portion, if not the whole earth, it is, we cannot but conclude, a fair inference, that this was the means by which such changes were produced. It is true, as some writers have stated, as an objection to a general deluge, that though the bones of many animals have been discovered, whose destruction has been attributed to that catastrophe, yet no examples of human beings have been found with them, or, indeed, in any situations which could be satisfactorily traced to the deluge, as the cause of their destruction. We have no doubt but the bones of animals, found in stratified rocks, were more ancient than the Noachian deluge, and that they lived and died, long before the creation of man. But that the remains of such human beings as were destroyed by that cataclysm, should not have been discovered, is certainly no more extraordinary, than that we should not find a single vestige of the millions who have perished in the sea, from the period of the naval actions of the Romans, and of other ancient nations, down to the present time. If it is agreed that all the people of the earth, except a single family, were swept into the sea, or otherwise perished in the water, we cannot suppose that their numbers, at that period, amounted to a hundredth part of the number which have since perished by the same means. Still, of all the latter, except in the floating, or recent state, no examples have been recorded. The fact, therefore, that no antediluvian human bones have been found, is certainly no stronger proof against a general destruction by the flood, than is the same fact a proof that the Romans and others did not perish by thousands, in their naval engagements. The not finding of bodies, it is true, is a negative fact; but we do not see why it does not equally prove that there was no deluge, and no naval engagements among the Romans.

CHAPTER XLII.

COAL;

ITS GEOLOGICAL SITUATION, ORIGIN, AND VARIETIES.

Importance of the subject.—THERE is no subject, within the range of geology, of more importance, than the natural history of coal; since the inhabitants of many countries are almost entirely dependent on its existence and quantity, for the enjoyments, and even comforts of life.

ORIGIN OF COAL.

We have already stated (15) that the geological writers of the present day, agree that all the varieties of fossil coal are of vegetable origin, and have also referred to some of the experiments by which this opinion has been confirmed, (21.)

629. *How coal-beds are formed.*—But though the vegetable origin of coal is satisfactorily established, there is still much difficulty in conceiving by what process, or repetition of processes, so many beds and seams of this substance have been regularly arranged over each other in the same place, each being separated by strata of sandstone, shale, or indurated clay. It will, perhaps, tend to simplify this inquiry, if we examine a single coal-field, of very limited extent, such as those which occur in small coal-basins, called by the miners *swillege*, and which are often not more than a mile in extent.

630. *These basins once small lakes.*—It seems evident that these basins were once lakes, and that the strata have been deposited on the bottoms and sides, taking the concave form, which form depositions in still water at first must assume, under such circumstances. But it appears, the largest quantity of original matter, at least in some cases, floated into the deepest water; for it is remarkable, that the stratum of coal, which in one of these basins is a yard thick, in the lowest part, gradually diminishes as it approaches the edges, and then entirely ceases. This fact proves that the present concave shape of this coal-bed, is the original one in which it was formed, and that the basin in which the materials, now turned to coal, were deposited, was a detached lake, and not an arm of the sea.

631. *Coal strata formed in water.*—It seems from the above, as well as from other geological facts, that coal strata were formed in the water, and no doubt the materials were accumulated by freshets or floods; but whether the place of deposit was in fresh or salt water, it is not always easy to determine. The shells found in coal-beds, according to Mr. Conybeare, are, at least sometimes, those of marine origin; but, on the other hand, the vegetable remains found in the same strata, are clearly those of the land, with no mixture of those of the sea. But there is sometimes much difficulty in distinguishing fresh-water and land, from marine shells, especially where no recent examples are known, with which to compare them.

632. *Known marine shells found in coal strata.*—It would appear from the account of Dr. Hildreth, of Ohio, that the coal-beds on the Muskingum river, in that state, have either been formed in the ocean, or that, since their formation, they have been submerged by salt water. "The lime rocks here," says he, "abound with marine shells of the genera Producta, Terebratula, and Spirifira, with Ammonites, and other chambered shells, indicating that some of the coal deposits have been deeply submerged under salt water, since their formation; or that the vegetable materials, composing the coal, had once floated in an ocean, and were precipitated by an accumulation of calcareous, argillaceous, and sedimentary materials, collected on, or about them, while floating."

"Marine fossils," continues the author, "are found both above and below the coal, and sometimes deposits, containing fresh-water shells, are intermixed, although they are not so common as they are nearer the Ohio river. Some of these fresh-water fossils bear a striking resemblance to living species now found in our rivers."—*Sill. Journal.*

633. *Quantity of vegetables required to form coal.*—It is not difficult to conceive that the earth might have produced a quantity of vegetation, even within the circuit of a few miles, sufficient to form a thick stratum of coal, though the thickness of this might bear a fractional proportion to that of the wood. Those who have seen the pine forests of our western country, can, perhaps, have some conception of the vast pile, which a single square mile of these trees would form, if thrown together. Now, if hundreds of square miles of such timber were accumu

iated in a lake, we might imagine that there would be a quantity sufficient to form, at least, one thick bed of a large coal-field.

634. *Drift-wood of the Mississippi.*—The quantity of drift-wood which descends the Mississippi, in the course of a few years, might be supposed to furnish ample matter for an extensive coal-bed. According to the estimates of Mr. Bringier, the quantity of floating timber which came down that river during a freshet, in 1812, amounted, for a considerable time, to 8,000 cubic feet per minute. The same writer states that the raft thus collected at the mouth of Red river, one of the tributaries of the Mississippi is 60 miles long, and in many parts 15 miles wide. Now, in case the bed of this river should, at some future time, be changed, so as to leave this immense raft covered with earth, which is by no means impossible, generations to come might here find an extensive coal-field.

635. *Ages of coal formations.*—There is no doubt but all the regular coal formations were deposited before the general deluge, or at that period when the temperature of the earth appears, by the remains of plants still found, to have been much higher than at present; and therefore, when all vegetables not only attained a greater size, but grew much more rapidly than they do in temperate climates. Hence, we may suppose that wintry torrents, or occasional inundations, denuded the earth of her vegetation to a great extent, and swept it into lakes or estuaries, in which case, it might well be imagined, that in such a climate, the earth would soon again be prepared with her vegetation for a similar sweep, and thus one stratum of coal after another would be formed.

During the intervals of these inundations, the operation of ordinary causes, as the flowing of rivers into these lakes, might bring down from the mountains the materials which have formed the clay and sandstone, now interposed between the beds of coal, in a similar manner to that now taking place at the mouth of the Mississippi, or that of other rivers.

FORM OF COAL-BEDS.

636. *Mr. Bakewell's comparison.*—Mr. Bakewell compares the shape of a coal-bed to that of a series of muscle-shells. "The position of coal strata, in many fields, may

be represented by a series of fresh-water muscle-shells, decreasing in size, laid within each other, but separated by a thin layer of clay. If one side of the shell be raised, it will represent the general rise of the strata in that direction; and, if the whole series be dislocated by partial cracks, raising one part a little, and depressing the other, to represent faults (389) in the coal, it will give a better idea of a coal-field than any description can convey."

"We are here to suppose that each shell represents a stratum of coal, and the partitions of clay the earthy strata by which they are separated. The outer or lower shell, represents the lowest bed of coal, which may be many miles in extent. Now, if a much larger shell be filled with sand, and the lower shell pressed into it, we may consider the large shell to represent limestone, and the sand, grit-stone; we shall have a model of the coal strata in many parts of England, and their situation over the metalliferous lime, with the beds of sandstone by which they are separated from it."—*Geology*, p. 117.

SEARCHING FOR COAL.

637. In most instances, the inclination, or bending of coal strata, is such that the veins rise nearly to the surface, and would be visible, were they not covered by soil or gravel. When this is the case, the removal of the soil by rivulets, or the accidental slide of a side-hill, will sometimes uncover the strata, so that their dip and thickness can be determined. This is a very fortunate circumstance, because the boring for coal, without some such indications that it exists, in greater or less quantities, even in coal districts, is a very uncertain means of its discovery.

LIGN. 113.

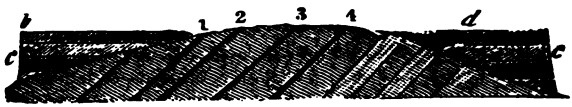
Coal strata.

638. *Borings are often made in the vicinity of coal, without success.*—Sometimes borings to a great depth have

been made in the immediate vicinity of large coal-fields, without producing any greater conviction of the existence of the mineral, than the surface before indicated. The cause of this will be seen by *Lign.* 113, where, suppose 1 is a coal-vein, and 2 a stratum of sandstone, below which is limestone, and that the basin is filled to the surface with slate and clay. Now, on boring at 2, it is evident that nothing but lime and sandstone would be found, though it might be within a few feet of the coal-vein; while, had the examination happened to have been made at 1, coal would have been found within a few feet of the surface.

639. *The dip and direction of the strata, to be observed.*—In examinations for coal, the dip and direction of the strata in the vicinity, should be carefully observed; for if the dip is towards the estate on which the search is to be made, it is probable that the coal may extend under it; but if the dip is in the contrary direction, the search ought not to be made, since experience has shown that it would be useless.

LIGN. 114.



Searching for coal.

The reason of this will be understood by *Lign.* 114, where 1, 2, 3, 4, are a series of coal strata, dipping towards *b*. The unconformable strata, *c c*, are sandstone, lying over the coal. Now, suppose the coal-vein, 4, makes an outcrop (384) at that point, on the estate of A, adjoining the estate of B, which lies towards *b*, then it appears that A would find only a part of the vein, 4, on his estate; and that it would be useless to search in the direction of *d* for coal, since the dip (383) of 4, is sufficient to prove that none exists there, unless indeed another coal-field should be found. Whereas, on the estate of B, though there might not exist an outcrop, still, the dip of that on the estate of A, would make it highly probable that B would find coal on his estate, though it might be too deep for working.

ANTHRACITE.

640. This name is from the Greek, and merely signifies *coal*, or *charcoal.* It is found in England, and is there known by the name of *stone-coal;* and in Scotland, it is called *blind-coal.* In this country, where it is found at many places, and in vast quantities, it is distinguished by the names of the places whence it comes: as, *Lehigh, Lackawana, Beaver*, and *Peach-orchard* coal.

Anthracite has been found only in small quantities in any part of Europe; but in this country, it forms the most extensive coal-fields known, and it now supersedes the use of wood as fuel, for culinary purposes, as well as for furnaces and steamboats, in every part of the country, bordering on the Atlantic. In the Western states, where bituminous coal chiefly prevails, this is employed instead of the anthracite.

Anthracite is distinguished from bituminous coal, by its greater weight and lustre; by its hardness and conchoidal fracture, and its burning without smoke, or blaze, or bituminous odors. Its odor is sulphureous.

AMERICAN COAL-FIELDS.

641. *Mr. Lyell's account of American coal-fields.*—Mr. Lyell, the distinguished English geologist, in his recent travels through the United States, records his astonishment at the vast extent of our coal measures. "The anthracite coal measures, occurring in the eastern, or most disturbed part of the Appalachian chain, are fragments or outliers of the great continuous coal-field of Pennsylvania, Virginia, and Ohio, which occurs about 40 miles to the westward. This coal-field is remarkable for its vast area; for it is described by Prof. H. D. Rogers, as extending continuously, from north-east to south-west, for the distance of 720 miles, its greatest width being about 180 miles. On moderate estimate, its superficial area amounts to 63,000 square miles. It extends from the northern borders of Pennsylvania, as far south as near Huntsville, in Alabama.

"This coal formation, before its original limits were reduced by denudation, (399,) must have been, at a reasonable calculation, 900 miles in length, and in some places, more than 200 miles in breadth."

642. *Chemical analysis of anthracite.*—Prof. Rogers has shown, by analysis, that this coal is most bituminous to

wards its western limit, where it remains level and unbroken; and that it progressively loses its bitumen towards the south-east, where the strata are bent and distorted. Thus, on the Ohio, the proportion of hydrogen, oxygen, and other volatile matters, ranges from 40 to 50 per cent. Eastward of this line, on the Monongahela, it still approaches 40 per cent., where the strata begin to experience some gentle flexures. On entering the Allegany mountains, where the strata is disturbed, but before the dislocations are considerable, the volatile matter is in the proportion of 18 or 20 per cent. At length, when we arrive at some insulated coal-fields, associated with the boldest flexures of the Appalachian chain, where the strata have been actually turned over, as near Pottsville, we find the coal to contain only from 6 to 12 per cent. of bitumen, thus becoming a genuine anthracite.

643. *Bituminous coal of Ohio.*—"I was truly astonished," continnes Mr. Lyell, "now that I had entered the hydrographical (water-formed) basin of the Ohio, at beholding the richness of the seams of coal, which appear every where on the flanks of the hills, and at the bottom of the valleys; and which are accessible to a degree I never witnessed elsewhere. The time has not yet arrived, the soil being densely covered with the primeval forest, and manufacturing industry in its infancy, when the full value of this inexhaustible supply of cheap fuel can be appreciated. I found, at Brownville, a bed ten feet thick, of good bituminous coal, commonly called the Pittsburg seam, breaking out of the river cliffs near the water's edge."

The boundaries of the Pittsburg seam have been determined with considerable accuracy. It is of an eliptical form, measuring 225 miles in one direction, and about 100 in the other.

644. *Great demand for this coal.*—So great are the facilities for procuring this fuel, that already it is found profitable to convey it in boats, for the use of steam-ships at New Orleans, a distance of more than 1,000 miles, although the intermediate river plains are densely covered with timber, which may be obtained at the cost of felling it.

"Again," Mr. Lyell continues, "while alluding to the vast area of these carbonaceous formations in the United States, so rich in productive coal, I may call attention to the Illinois coal-fields. * * * That coal-field, com-

prehending parts of Illinois, Indiana, and Kentucky, is not much inferior in dimensions to the whole of England; and consists of horizontal strata, with rich seams of bituminous coal." (*See Travels*, vol. ii. p. 25–6.)

CHAPTER XLIII.

METALLIC VEINS;

THEIR PHENOMENA AND CONTENTS.

645. *Veins originally fissures.*—METALLIC veins appear originally to have been fissures, often passing through different beds of rock, and which were subsequently filled with metallic ores. These veins must therefore be considered as subsequent formations to the rocks through which they pass. When, however, a vein is found in only one bed of rock, the vein may have been formed and filled at the time when the rock was consolidated.

When mineral veins occur in considerable numbers in any tract of country, they maintain a general parallelism, as if all the fissures to which they owe their origin, had been formed at the same time, by some common cause.

The absolute antiquity of veins cannot be conjectured; but where one vein intersects another, as is often the case, the dislocation of the strata, through which the oldest vein passes, by the contact of the new one, is sufficient to show a difference in their ages.

646. *Exist in hypogene rocks.*—Veins exist in hypogene and metamorphic rocks, but are most common in the former. The substances most commonly found in them, are the *metals*, *quartz*, *calcareous spar*, *barytes*, and *Derbyshire spar*. It hardly need be remarked, that the chief object in pursuing veins, is the metals which they contain.

With respect to the depth of metallic veins; nothing but conjecture can be offered. The miners believe that they reach quite through the earth, but this opinion has no other foundation than that they never find their termination. Indeed, it is believed, that no instance has been recorded, where the end of a metallic vein has been found. They, however, often grow too poor to pay the expense of

working; and the difficulty of clearing deep mines of the water, is a frequent reason why they are relinquished, when they would pay a good profit, were they near the surface. Veins are seldom rich near the surface; but increase in value at a medium depth, and grow poor again at a greater.

647. *Change of metals at different depths.*—Metallic veins often change their metals at different depths. In France, there are veins which contain iron above, then silver, and below the silver, copper; and one of the Cornwall mines contains zink, in the upper part of the veins, which becomes rich in copper at a greater depth. Veins often change their dimensions also, being narrow in some parts and wide in others. Thus, the Dalcoath mine of Cornwall, varies from forty feet to six inches in width.

It is a curious circumstance, that where a vein is intersected by a dike, that the former often divides into two branches, which unite again before reaching the latter, and after having passed it, separates into several ramifications.

LIGN. 115.

Metallic veins.

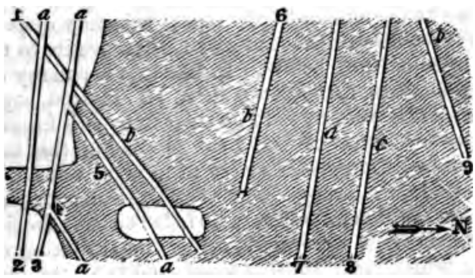
Thus, *Lign.* 115, *b b*, is the dike, and *a a*, the metallic vein, divided at *a*, but united again before reaching the dike, after passing which, it again separates into several parts. The dike has occasioned a fault, by which the two ends of the vein are widely separated. The lower branches are not supposed to terminate as represented in the cut, but to unite again, and proceed downwards. *c c*, shows how veins sometimes change their dimensions, being narrow in some parts and wide in others.

648. *Cornwall tin mine.*—Sometimes veins containing different metals cross each other, and, as above stated, pass

from one kind of rock into another. Examples of both, are contained in the tin Croft mine in Cornwall.

In this mine are five copper veins, three of tin, and one mixed, all within about a furlong of space, from north to south. Two of the tin veins proceed in a straight line, the other alters its course repeatedly, in a gradual approach to the perpendicular, and is intersected by two of the copper veins. The rocks through which these veins pass, are slate and granite.

LIGN. 116.



Metallic veins.

The annexed *Lign.* 116, from Mr. Phillips' paper on this mine, will make the direction of these veins understood. *a a*, copper veins; *b*, tin veins; *c*, copper and tin intermixed. The dark shade is slate, and the white parts granite. The vein number 3, passes between slate and granite, one of these rocks being found on the north side, and the other on the south. Detached masses of granite and slate are found in this vein, and also in number 2. In this mine it was frequently the case, that where the vein was passing through slate, it contained fragments of granite, and when passing through granite, it contained pieces of slate.

CHAPTER XLIV.

THEORY OF VEINS.

VARIOUS OPINIONS CONCERNING THEM.

649. *Hutton's theory.*—No subject belonging to geology, has been contested more warmly, than the theory of metallic veins. These may be considered analogous to dikes, which are veins of stone penetrating strata differing from themselves in kind; and it is hardly disputed at present, that dikes have not owed their origin to melted matter injected from below. In like manner many of the earlier geologists, and among them Dr. Hutton, supposed that the metals were forced into their veins in a fused state, the expansive force of the heat producing the fissures. This is called the *igneous theory* of mineral veins.

650. *Werner's theory.*—Opposed to this doctrine is that of Werner, and his followers, who believed that the fissures of dikes and veins were produced by the shrinking of the rocks in which they are contained, and that the metallic veins were afterwards filled with the metals in a state of solution, poured in from the surface of the earth. This is called the *aqueous theory.*

651. *The aqueous theory not satisfactory.*—From the facts we have stated concerning veins, and what will be stated directly, the reader will see, that this latter theory contradicts, at once, the principal phenomena by which they are attended. For even were it shown that the metals were soluble in water, which, however, cannot be true, still, the supposition that the fissures were filled from above, could not be maintained, for the following reasons: First. The ores of most veins are unmixed, but where a vein contains several metals, one kind is above or below the other. Were the metals poured in from the surface, no reason can be assigned why the several solutions should not have fallen in together; or why one should have filled the lower part of the vein and the other the upper. Second. When a vein passes through a different kind of rock, as from sandstone through limestone, the quality of the ore is changed, and it becomes richer or poorer. This is a general fact well known to miners. Now, it is plain, that were

these veins filled by solutions poured in, the kind of rock could not possibly influence the quality of the metal. Third. When a fault changes the strata through which a vein passes, by lifting that on the one side, or throwing down that on the other, so as, for instance, to place sandstone on one side of the vein, and limestone on the other side, the vein is never so rich in ore, as it is when both sides are of the same kind of rock. This fact is also plainly incompatible with the aqueous theory. Fourth. Were the metals poured in from above, we should expect that all the narrow parts of the veins would soon be filled with earth mixed with the solutions, and, therefore, that they would reach only to a short distance below the surface; whereas the termination of a vein, as already stated, has never been discovered. Many other objections might be stated; but these are sufficient to show that the aqueous theory is incompatible with the known phenomena which metallic veins present.

652. *Difficulty of the igneous theory.*—If now we advert to the igneous theory, we shall find fewer absurdities, because much must here be left to conjecture; but the difficulties are little less than those of the aqueous.

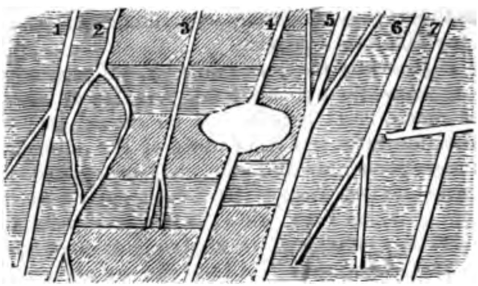
The objections already made, may be applied, without modification, to this theory; for if the metals were injected in a state of fusion from below, as we must now suppose, how would any change in the kind or position of the strata, change their quantities? and how can we account for the fact, that veins in the same vicinity contain different kinds of metal, perfectly distinct, as tin and copper, in the Cornwall mine? Besides these objections, the heat of the fused metal would have produced obvious effects on the walls of the veins, as is the case with basaltic dikes. The adoption of either of these theories is therefore only a choice of dilemmas, as they both fail entirely to account for the phenomena observed.

653. *Neither theory explains the facts.*—But the difficulty concerning metallic veins, does not end here; for were it shown, in the most satisfactory manner, how the metals might have been soluble in water, and in what way they might have been introduced from the surface into the fissures; or, on the contrary, could it be made to appear that all the phenomena which veins present, were compatible with the igneous theory, still, the great difficulty would

remain unanswered, viz: *whence did the metals come, before they were melted by the heat below, or dissolved by the fluid above.*

654. *Whence do the metals come?*—This, after all the arguments that have been employed on both sides, is the principal question; and the reasonable answer is obvious. The metals were created by Him who made the other parts of the earth; but whether they were formed at the same time, and in the veins as we see them, or whether the veins were fissures, afterwards filled with the metals; and, if so, whether they came from below, being dissolved by heat, or from above, in solution with some fluid, are questions which man, with all his curiosity, seems destined never to answer.

LIGN. 117.



Theory of veins.

The adjoining cut represents the most common varieties of metallic veins. It is from Sir W. T. Brande's "Outlines of Geology," and is placed here to gratify the curiosity of the reader, on this mysterious subject.

With respect to the direction of different metallic veins, we have already observed, that in the same neighborhood. they commonly run parallel with each other, and are often nearly, or quite vertical, or perpendicular to the line of the horizon. But the inclination of different series of veins is found at every angle, from the perpendicular to the horizontal; and the manner in which they run among the strata is also exceedingly various. In most instances, the line of the vein is across that of the strata; but sometimes they run parallel with each other, and the veins spread

out between the strata, as represented at No. 4. Sometimes, also, a vein, whose general direction is across the strata, will take a short turn between them, and then proceed on as before, as represented at 7. The branches of the veins do not terminate as they seem to do in the figure, but commonly join themselves together again, as seen at 2.

655. *Metallic veins do not consist of metals alone.*—It must not be understood that metallic veins consist of metals, or their ores alone; on the contrary, they are mixed with greater or less proportions of stony matter. Sometimes the ore is diffused through the vein, in the same manner as it would be, had the stone been porous, and dipped into a solution of the metal. In other instances, the metal lies in concretions, or crystals, entirely surrounded by the stone. An instance of this is common in the sulphuret of iron, the crystals of which appear as though they had been perfectly formed, and then dropped into the stone when in a soft state. Indeed, so mysterious are the phenomena which metallic veins exhibit, as, in the present state of knowledge, to defy all hypothesis.

CHAPTER XLV.

CHANGE OF CLIMATE.

THE CLIMATE OF THE NORTHERN HEMISPHERE WAS ONCE TROPICAL.

656. *Importance of the subject.*—This is a subject of great importance to geology; and although the idea of a universal change of climate, was once strongly controverted, most writers on the subject, at the present day, consider that there is sufficient evidence that the temperature of the atmosphere, and the earth's surface, is much lower than formerly.

657. Indications by the remains of plants.—It has already been stated, under the head of "Fossil Botany," that in many instances, plants growing at present only in the hottest climates, have been found in the fossil state in many parts of Europe and North America. Indeed, it is ascertained that the vegetables of which the carbon-

iferous strata are composed, both in England and in this country, are almost exclusively those of tropical climates.

The *Equisetums*, (144,) which, in the Northern hemisphere, are found at the present day no larger than the finger, have been discovered in the coal-mines of England, from four to six inches in diameter, and probably of proportionate height.

The *Caulopteris*, (159,) or arborescent ferns, now found only in the fossil state, were, from the diameters of their trunks, undoubtedly the rivals of forest trees of the present time, in size. The largest ferns now growing in temperate climates, rise only to the height of five or six feet; while in the same climate, the remains of this tribe occur, which indicate a height of thirty, or even fifty feet. We have already mentioned a fern from Bengal, forty-five feet high, (79.)

The *Lycopodiums*, (167,) *Sigillaria*, (160,) and the *Calamites*, (145,) found in the fossil state, are each similar examples of gigantic vegetation, when compared with the species of these genera now growing in various parts of the world.

658. *M. A. Brongniart's remarks.*—M. Adolphe Brongniart, in his splendid work on fossil plants, comes to the following conclusions on this subject: First. "That in the strata of coal and anthracite, the vegetables preserved are nearly all Cryptogamous or Monocotyledonous plants, (69,) as ferns, equisetums, and lycopodiums, and that some of these tribes, which no longer exist, except as fossils, grew to an immense size in Europe.

Second. "That in the higher strata, a great variety of fossil vegetables exists, which, for the most part, appear to belong to similar tribes of plants, if not in species, at least in genera, to vegetables which still inhabit the hottest regions of the earth; nor is it probable that they have been transported to the places where they are found in Europe, from such climates, since their most delicate parts are uninjured. It is, therefore, reasonable to suppose, that since the growth of these vegetables, the climate of Europe has suffered a great change."

659. *The Palms.*—Still stronger indications of a change of climate are evinced, by the occurrence of the remains of various species of palms, both in Europe and North America. These are now found, it is well known, only

in intertropical climates, where they are among the most graceful and magnificent of vegetables. That these once were natives of the Northern hemisphere, there cannot be the least doubt; for, besides being found in abundance in coal strata, they have been discovered, with their roots still in the earth, showing, beyond dispute, that they could not have been transported from a warmer region, but that they once flourished in the places where their petrified stems are still to be seen.

660. *Inferences.*—From all these facts, about which there can be no dispute, the inference cannot be avoided that, what are now temperate, were once tropical climates; since all the species of plants above named, are natives of such climates, and refuse to grow in any but the warmest parts of the earth.

661. INDICATIONS BY THE REMAINS OF ANIMALS.—"That the climate of the Northern hemisphere has undergone an important change," says Mr. Lyell, "and that its mean temperature must once have resembled that now experienced within the tropics, was the opinion of some naturalists who first investigated the contents of ancient strata Their conjectures became more probable, when the shells and corals of the secondary rocks, were more carefully examined: for these organic remains were found to be intimately connected, by generic affinity, with species now living in warmer latitudes. At later periods, many reptiles, such as turtles, tortoises, and the larger saurian animals, were discovered in the European strata, in great abundance; and these supplied new and powerful arguments from analogy, in support of the doctrine, that the heat of the climate had been great when our secondary formations were deposited. Lastly: when the botanist turned his attention to the specific determination of fossil plants, the evidence acquired the fullest confirmation; for the Flora of a country is peculiarly influenced by its temperature; and the ancient vegetation of the earth might more readily than the forms of animals, have afforded conflicting proofs, had the popular theory been without foundation."

662. *Remains of the Saurians, a proof of change.*—The remains of the *megalosaurus*, (180,) the *ichthyosaurus*, (276,) and several other colossal animals of the same tribe, the genera of which, if any examples are still in existence, are known to inhabit only the hottest portions of the earth

being discovered in English strata, are strong proofs that the climate of the country was once much warmer than at present. "It is true," says Dr. Mantell, "that these animals no longer exist, and therefore only indicate a change of climate, by the analogy, that animals of similar tribes, and of great size, are found exclusively in tropical climates at the present day. But there is not wanting other evidence of such a change, and, perhaps, as direct as the nature of such a case will allow, in the fact clearly proved by Dr. Buckland, that quadrupeds once inhabited Europe, the genera of which are known to live only in tropical climates."

663. *Dr. Buckland's discovery of the remains of tropical animals.*—The genera of quadrupeds which Dr. Buckland was able to determine from the bones found in the Kirkdale cavern, an account of which has already been detailed, (page 191,) amounted to 23. Of these, the elephant, rhinoceros, hippopotamus, tiger, and hyena, all belonged to hot climates; and it is well known, that the species now living, cannot exist in the climate of any part of Europe, without the protecting care of man. That these animals all perished at, or near the place where their remains were found, is proved by Dr. Buckland, by the strongest evidence which such a case could allow; and, therefore, that they were inhabitants of that country, admits of no doubt; and, if so, then these animals must have changed their nature and habits, or the climate where they lived must have materially changed its temperature.

CHAPTER XLVI.

WELLS AND SPRINGS;

THEIR GEOLOGICAL SITUATIONS AND PHENOMENA

664. *Origin of common springs.*—The origin of common springs is easily understood. The water which falls on the surface of the earth, penetrates its substance, until meeting with a stratum of clay or the surface of a continuous rock, which hinders its descent, it accumulates; and, taking the direction given by these

impediments, continues its course, until, meeting with an aperture, it gushes out in the form of a spring.

LIGN. 118.

Common springs.

Suppose *a*, *Lign.* 118, to be a gravel hill, and *b*, strata of clay or rock, impervious to water. The fluid, percolating through the gravel, would reach the impervious strata, along which it would run until it found an outlet at *c*, at the foot of the hill, where a spring would be formed. As water in the earth observes the law of gravity, springs are most commonly found lower than their sources. When, however, the fluid is intercepted by a dike, which rises as high as its source, the hydrostatic law of tending to a level, will carry it equally high; though this in fact is probably not a common circumstance, since the pressure of the water generally will find an outlet before it rises to such a height.

665. *Artesian wells*—The people of Artois, in France, for a long time have been in the practice of boring into the earth, until they find a sheet or vein of water which rises to the surface. These are called *Artesian* wells, because the method was first invented or employed in Artois.

This method has for many years been practiced in other parts of Europe, and more recently in this country. The size of the boring is usually three or four inches in diameter, and to prevent its sides from falling in when it passes through a stratum of sand, there is introduced a jointed tube, which in Artois, is made of wood, but in other countries, of copper or other metal. It often happens that, after passing through hundreds of feet, without success, a vein of water is pierced, which immediately ascends to the surface, and flows over the end of the tube. The first rush of the water is sometimes so violent as to throw it many feet above the surface, where for a time it plays like an artificial fountain, and then continues to run

in a steady stream, or perhaps sinks away below the surface, to the great disappointment of the operator. This violent gush of the water appears to be owing to the pressure of air or gas on its surface, before it was pierced by the auger. Dr. Hildreth states that in boring for salt in Ohio, the gas rushed out with such force as to throw the auger and poles into the top of a tree.

In some instances, large quantities of water have been discharged from great depths in this manner. In 1824, a well was dug at Fulham, near the English Thames, to the depth of 317 feet, the deepest part of which passed through sixty-seven feet of chalk. On piercing through the chalk, the water immediately rose to the surface, and discharged itself at the rate of fifty gallons per minute.

666. *Deep well without water.*—Sometimes boring for Artesian wells is entirely without success. Thus, at Toulouse, in France, the excavation was carried to the immense depth of 1,260 feet, and abandoned without finding water. In most places, indeed, there is no doubt but success must depend on chance, since neither skill nor experience, in ordinary circumstances, can ascertain, beforehand, the direction of a water-vein. It appears, however, that in certain situations, water-bearing strata underlay considerable extents of country, as will appear by the following account:

667. *Artesian wells at Modena.*—In the country about Modena, in Italy, to find water, they dig through several kinds of soil, until they come to a stratum of hard calcareous clay, which resembles chalk. Here they begin their mason work, and build the wall at their leisure, carrying it up to the surface, without the least sign of water. But experience has taught the workmen not to expect it until they pierce this stratum, when it never fails to reward their labors. When the well is finished, they bore through this hard stratum with a long auger, but take care to leave the well before they draw it out again; which, when they have done, the water springs up into the well, and in a short time rises to the brim, or in some instances, overflows into the neighboring valley.

The source of these wells is supposed to be in the Appenine mountains, which lie not a great distance from Modena, and to which the impervious stratum does not reach. The water from the mountains, therefore, sinks

below this stratum, at a distance from these wells, and is thus prevented from rising to the surface until this is pierced.

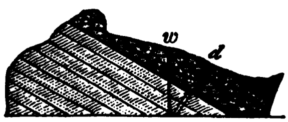
LIGN. 119.

Artesian wells.

Suppose *a*, *Lign.* 119, to represent the Appenines, sloping down towards Modena, and passing under the secondary strata at *b*. Suppose that the impervious strata, *c*, does not reach the side of the mountain, and that the strata, both above and below it, admit the water through them; then the fluid would not rise in any quantity above this stratum, except about its edges; but the pressure being constant on its lower side, because the source is elevated, the moment this is pierced, the water flows above it, as at *w*, which represents a well.

668. *Overflowing wells.*—In many instances, wells overflow their brims, and continue to discharge water, in the manner of springs. These may be springs deeply situated, which happen to be struck by the well, or they may be dishes of water, confined by dikes, or by impervious strata, inclining towards each other.

LIGN. 120.



Overflowing wells.

The annexed cut, *Lign.* 120, represents inclined strata covered with alluvial deposits. The water descending along the strata, would be lost in the adjoining valley was it not intercepted by the dike *d*, which serves as an impervious dam. The water, therefore, rises, and forms

springs along the inside of the dike. Now, if a well be sunk at *w*, the water will rise to the surface of the ground, and if the inclined rocks be considerably higher than the well, it will overflow. If the strata form a dish, one side of which is considerably higher than the other, the same effect will be produced.

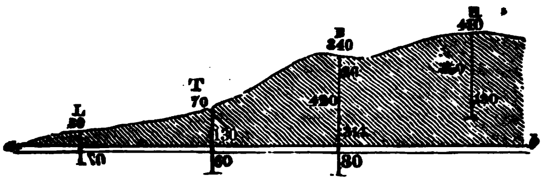
669. *London wells.*—London, and its vicinity, stand over a formation of rather a peculiar kind, called *London clay*. Its direction is nearly horizontal, and its thickness from 100 to 500 feet. It is covered with alluvial deposits, of various thickness; so that although the surface of the clay may be horizontal, still, the depths of the wells are various, according to the thickness of the alluvium. Until within a few years, most of the wells in and about London were sunk no deeper than the surface of this clay, and its impervious nature is of vast importance to that great city, since the water is thus retained, and a plentiful supply is always furnished by means of shallow wells. But this water, though limpid, is hard and impure. That, however, which is drawn from below the clay, is perfectly soft and transparent; and hence all the pumps about London, which furnish such water, are of great depth, piercing the sand below the clay.

This water, says Mr. Conybeare, frequently rises so instantaneously, on passing through the clay, as not to suffer the well-digger to escape, without rising above his head. It appears to rise in different places to different heights. Thus, at Liptrap's distillery, near the Thames, it rises no higher than the level of that river; but at Tottenham, 4 miles north of London, it rises 60 feet above that level; while at Epping, 15 miles north of London, the water rises to within 26 feet of the summit of the well, which is 340 feet above the level of the Thames, and therefore 314 feet above that level. This well is 420 feet deep, of which 200 feet were sunk through by digging, and 220 bored with an auger, 4 inches in diameter. After boring to this depth, no water being found, the project was relinquished, and the well was covered over; but at the end of five months it was found that the water had risen to within 26 feet of the surface, and has so continued ever since. The sinking of this well was, therefore, 340 feet above the level of the Thames, and 80 feet below it.

670. *Well at Hunter's Hall.*—A well at Hunter's Hall

is 350 feet deep, but its summit is 70 feet higher than that at Epping, and 410 feet above the level of the Thames. The water in this well stands 130 feet above its bottom, which is 60 feet above the level of the Thames; the actual elevation of this water, therefore, is not so great as that at Epping, by 54 feet.

LIGN. 121.



Deep well at Hunter's Hall.

These facts will be better understood by *Lign*. 121, where H marks Hunter's Hall; E Epping; T Tottenham; L Liptrap's well, at Mile End. *a b*, is the level of the sea, as indicated by that of the Thames. It will be observed that all the wells reach below the level of the Thames, except that at Hunter's Hall. The numbers will be chiefly understood, by the explanations already given. Thus, the water in the well at Hunter's Hall, stands 130 feet from its bottom, the well is 350 feet, and its mouth 410 above the level of the Thames. That at Epping, is 420 feet deep, its summit is 340 feet above the Thames, and its bottom 80 feet below it; the water is 314 feet deep, and it rises to within 26 feet of the top. The well at Tottenham is 130 feet deep; its top is 70 feet above the Thames, and its bottom 60 feet below it, and the water rises 60 feet above the sea.

All these wells being sunk below the London clay, and deriving their water from the same source, it might be expected that, agreeably to the general law of hydrostatics, their surfaces would have a common level. The London clay is nearly on a horizontal level; the depth of the well at Hunter's Hall, however, shows a slight rising of the strata there; but still, the water in that well does not rise so high, by 54 feet, as that in the well at Epping.

671. *Common wells.*—Wells situated in level countries

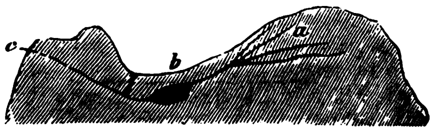
and in alluvial formations, generally require to be sunk only 30 or 40 feet, and sometimes no more than 20, before water is found. These are not commonly supplied by springs, but merely by the draining of the water, which exists within the circuit of a few yards, into a cavity. During severe droughts, many such wells fail, which shows that they are supplied only by the rain which percolates from the surface, and not by deeply-seated springs.

672. *Springs in salt marshes.*—There is little difficulty with respect to those springs which rise in salt marshes, or which gush from the fissures of rocks under the sea. The sources of these are in the distant hills; or in the strata of the vicinity, situated higher than their outlets; and the presence of the sea or marsh, it is plain, could not affect them, since the water from these does not penetrate their sources. This principle will also account for such springs as rise on small islands, at little distances from the sea-shore, where they could not have been collected from the rain falling there.

673. *Springs on the tops of hills.*—There are, however, springs which rise near the tops of hills, and which are so situated as to make it apparent that their sources could not exist in the same hills, nor in those in the immediate vicinity. The water with which such are supplied, must, therefore, come from the higher hills or mountains, at a distance, and, passing the intervening valley, rise by hydrostatic force to these outlets. Many rocks are so full of fissures, as to present no difficulty in supposing that considerable rivulets might run among them, at great depths below the surface. Rocks also frequently contain large cavities, so that some rivers sink down into them, and disappear for miles, when they again issue from their hiding-places, and continue their courses. In limestone districts, it is well known that large cavities are of common occurrence. Perhaps, therefore, the manner in which water is conveyed to the springs, situated as above described, may be as follows:—Water, from hills at a distance, and more elevated than the springs, descends through fissures, to a cavity in the valley, which cavity communicates with another fissure, running to the spring. In this manner the hydrostatic pressure from the highest hill, would overcome that from the lower one, and the water would be perpetually transferred from one to the other.

Such a well exists near the city of Hartford, called the *Overflowing well*, and is a well-known curiosity to inquiring strangers, who visit the place.

LIGN. 122.



Hydrostatic springs.

The annexed cut, *Lign.* 122, will make this obvious. The rills *a*, are supposed to unite, and fall into the cavity, below *b*, from which the greater pressure from *a* forces the water up the hill, through a fissure, to *c*, where the spring issues.

674. *Streams under the earth.*—That water runs in considerable streams under the earth, and among the fissures of rocks, is proved by its issuing in springs, sometimes in large quantities. Dr. Macculloch states, that a spring in Staffordshire, is computed to discharge more water annually, than all that falls in the surrounding country; and the same, even to a greater degree, is true of that of the Sorgne, in France.

675. *Big Spring in Virginia.*—A writer in Featherstonhaugh's Journal, for August, 1831, p. 65, refers to a great body of water, which issues from the ground, 10 miles from Harrisburgh, Virginia, and which is known under the name of "Big Spring." He says: "It should rather be called a river, so large is the body of water which rises suddenly from the foot of a limestone hill, and continues in a stream some yards in breadth, and half a foot deep, with force sufficient to turn two large mills immediately below."

676. *Spring at Kingston.*—There is a spring at Kingston, R. I., which rises from primitive rocks, and discharges such a quantity of water, that a grist-mill has been driven by it for a great number of years; and more recently, a large cotton factory has been erected below the corn-mill, which depends entirely on the water of this spring to turn its whole machinery.

From these, and such like facts, there can be but little

doubt, that small streams are constantly running under ground, among the crevices of the rocks, and that such springs are formed by a union of many of these tributaries, in a similar manner to which larger streams are formed on the surface of the earth, by the union of several smaller ones.

CHAPTER XLVII.

THE GLACIERS;

THEIR MOTIONS, PHENOMENA, AND THEORY.

677. The attention of the scientific world has lately been turned to the investigation of the subject of *Glaciers;* and such has been the interest they have attracted, that many volumes have been written in explanation of the phenomena they exhibit. Indeed, no department of Geology, at the present time, excites such keen interest as this. It is therefore proposed here to give such an account of the subject as to make it clearly understood.

678. *Definition.*—A glacier is an accumulation of ice and snow on the side of a mountain, whose summit reaches the line of perpetual congelation. In general, this continuous mass reaches down the side of the mountain gorge until it meets the heat of summer. The sides of the Alps of Switzerland, are in many directions covered by glaciers, and it is here that their phenomena have chiefly been studied.

A glacier is not a mass of solid ice, but is loose in its texture, and often stratified by layers of ice and snow, alternating with each other. It is rough on the surface, and is better represented by a frozen torrent than a frozen lake. In the summer season the lower part melts, and affords a continual flow of water. Perhaps this extremity may terminate in the very field where the crops of corn and the green grass are growing in all their beauty and luxury.

In the lower part, the glacier is constantly wasting by fusion during the summer, nor does the snow of winter, in many instances, compensate this loss. In the upper part, the heat of the summer sun also melts large portions of

the surface, but the accumulation of winter often more than supplies this loss. If, therefore, these masses were fixed like the rocks on which they rest, the lower portions would entirely disappear, while the upper would cover the highest mountains by their constant increase, and yet it is found that ages produce little change in their relative proportions. This, we shall see, is explained by the constant motion of the glacier from the mountain towards the valley, and yet it never leaves the mountain, nor fills the valley.

679. *Motion of the glacier.*—Although the form or appearance of a glacier may not, so far as the eye can detect, change for years, or even centuries, yet it is certain that the whole mass, extending many leagues in every direction, is in constant motion down the inclined plane on which it rests. Nor can any impediment, such as the irregularity of the surface, or the narrowness of the gorge through which it passes, arrest this movement. This at first might seem an enigma of difficult solution, and yet no geological fact is more clearly ascertained, though the cause which produces a force so enormous is so entirely concealed—so silent in its action, as to divide the opinions of the acute philosophers, who have witnessed all the facts, as to its nature. On this point, we shall hereafter cite the opinions of different observers.

680. *Proofs of glacial motion* —The glacial masses are so extensive, often 20 or 30 miles in length, and their motions so slow, that particular means are necessary, first, to detect this movement, and then to ascertain the rate of motion.

In order to ascertain that these vast bodies actually move, some fixed object, as a permanent rock, must be selected as a point from which observations are to be made, and then taking a block of stone, resting on the surface of the glacier, as the moving body, and accurately noting their relative positions, both the motion of the icy suface, and its rate, can be ascertained.

That the glaciers move, has been long since proved by the observations of the neighboring inhabitants, as well as those of philosophers. A block of stone, of peculiar shape or size, seen at a distance on the surface of the glacier, and year after year approaching the house or the field of a peasant, until, by the melting of the ice in summer, it was

left on the bare ground, would be a sufficient proof of motion. But philosophers have not been satisfied with this proof; they have observed, scrutinized, and measured for themselves.

Sometimes accident has furnished the means of ascertaining the glacier motion in a very peculiar and striking manner. This was the case with respect to Saussure's ladder, a fact mentioned by many of the writers on this subject. This celebrated philosopher visited the Alps in 1788; and, for the purpose of ascending steep places, had a ladder conveyed with him nearly to the head of a certain glacier. This ladder, it seems, was left at a certain place known to the guides. After a lapse of forty-four years, the very same ladder was found at the distance of 16,500 feet from the place where the philosopher had left it.

681. *Rate of glacier motion.*—Admitting that Saussure's ladder traveled as stated above, its motion was at the rate of 375 feet per year, or a little more than a foot per day. But it can hardly be otherwise than that the motion of these huge masses must depend on the circumstances of inclination, the surfaces over which they run, perpendicular impediments, and perhaps other contingencies unknown to man. It is known that there is a great difference in the rates at which they move at different periods, and also that some descend nearly, if not twice as fast as others.

One of the most interesting and satisfactory accounts of glacier motion is contained in the narrative of Professor Agassiz, who has written largely on this subject, his work being illustrated by many views, which are said to be exceedingly correct.

"The most incontestible proof," says he, "of the descending march of glaciers, is afforded by the observations which I made last year (1839) on the lower glacier of the Aar. My intention was to visit the point of junction of the glaciers of the Finster Aar, and Lauter Aar, where M. Hugi had constructed a cabin in 1827 for passing the night. We had walked for nearly four hours on the great medial moraine, when we discovered, all at once, a cabin, very solidly built. We did not think that this could be Hugi's cabin, for we knew that it had been constructed at the foot of a certain rock, which forms the angle of the mountain, separating the two glaciers, and we were yet a

great way from this rock. It also seemed that the walls of the cabin were too well preserved to have resisted for twelve years the hurricanes of these elevated regions. It was, however, the very cabin of M. Hugi, which we had thus recognized. We found a broken bottle under a little heap of stones which served to fix a long pole on an immense block of stone, situated at one side of the cabin. This bottle contained several papers, which informed us that M. Hugi had constructed this cabin in 1827, at the foot of a certain and well-known rock, called, in the language of the country, *Abschwung*. Another paper, in the hand-writing of M. Hugi, informed that in 1830 he had returned to his cabin, and found it several hundred feet below its first position; that six years afterwards, (in 1836,) he found it 2,200 feet from the foot of the rock where it was constructed. We hastened, continues Prof. Agassiz, to measure with a long cord, which we had provided, the distance from the cabin to the rock, and found it 4,400 feet. This year, 1840, I have found the cabin much injured, but 200 feet down the inclined plane from where it was last year."

682. *Their motions not uniform.*—From this extract we find, by calculating from the numbers given, that the motion of this glacier has been far from uniform. During the first nine years, from 1827 to 1836, the whole distance passed over, being 2,200 feet, was less than 250 feet per year; while during the three years from 1836 to 1839, it must have moved three times as fast as before, since the same distance was passed, making 730 feet per year. Whether any circumstance with respect to the position of the ground, or of the seasons, during these years, afford any data from which a conjecture might be raised to account for this difference, we are not informed.

Says a writer on this subject, "What curious internal evidence, then, does a glacier present, of the progress of events which have modified its surface. It is an endless scroll, a stream of time, upon whose stainless ground is engraven the succession of events, whose dates far transcend the memory of living man. Assuming, roughly, the length of a glacier to be 20 miles, no uncommon case, and the velocity of its progression one-tenth of a mile, or 500 feet per year, the block of stone which is now being discharged from its lower or inferior surface on the terminal

moraine, may have started from its rocky origin two hundred years ago."

683. *Moraine.*—This is a word which often occurs in all recent descriptions of the glaciers; and although the latter may occur without the former, yet so intimate is the connection, that no moraine exists, without at least the supposition of a glacier by which it has been formed.

A *moraine* is the accumulation of stones, sand and earth, brought down and deposited by the glacier. The formation of these deposits is explained by Prof. Agassiz as follows: "Glaciers, it is well known, are continually moving downwards, (the cause of which will be explained hereafter.) In their course down the mountain, rocks and earth are often deposited on their surfaces, being loosened by the frost or streams of water. These accumulations continue on the surface of the ice, until they reach the valley, where the heat of summer, melting the lower part of the glacier, they are deposited and left on the bare ground, sometimes miles in extent and many feet in thickness. Sometimes, also, the weight and force of the moving glacier is such as to plough up the soft earth several feet in depth, carrying the soil, together with the rocks and stones, forward, and finally leaving them, whenever this force is lost by being dissolved into water by the influence of summer."

684. *Glacier tables.*—It is a curious fact, that although dark-colored blocks of stone, of all sizes, rest upon the surface of the icy glacier, and are there exposed to the heat of the summer sun, yet they never absorb heat so as to sink down into the ice by melting. The experiment of Franklin, in placing pieces of cloth of different colors on the snow, to test their respective powers of absorbing heat, by the distances they sunk below the surface, seems not to hold with respect to the glaciers. On the contrary, there is a continual waste of the ice around the blocks of stone, but not under them, so that instead of sinking beneath the surface, they in effect rise above it, by the waste which takes place around them. Thus, the stones are elevated on pedestals, or tables, and hence the name. These icy pedestals, raised in many instances several feet above the general level, each crowned with a stone on its top, are said to give some of the glaciers a singular and enigmatical appearance. The stranger wonders by what

unseen and mysterious power the ice has been thrown above the common level, carrying with it such a huge block of granite. But this fact points to a most important circumstance in the economy of glaciers, namely, that there is a perpetual waste at their surfaces. The stone, therefore, by preventing this waste, is an index to the former level of the whole mass, like the pillars left during an excavation into the earth. A few authors formerly supposed that these icy tables, by some singular process, started up from the general mass, but more patient and accurate observation has left no doubt that their origin is as above described.

A very simple experiment has been made, to show the gradual wasting of the glacier, as it descends towards the valley. A hole ten feet deep being cut in the ice, a stick was set vertically therein, leaving a few feet above the surface; when observation showed that the stick was several feet higher above the surface, in the autumn than in the spring.

685. *Composition of the glaciers.*—It is a great mistake to suppose that glaciers are composed of solid ice; on the contrary, especially near the surface, they are exceedingly porous, and during the summer are so soft as to allow the foot to sink into the surface at every step.

The upper portion of the glacier, consisting of unconsolidated snow, is called, in French, névé. As we approach this part, the fissures or crevices, which in the lower parts are very common, become more rare, and are always narrow. At the elevation of about 8,000 feet, the winter's snow lies all summer, with very little melting. It, however, gradually becomes more and more solid, and the new snow is always easily distinguished from the old, by the icy texture of the latter. This portion of the glacier often presents a magnificent prospect, the surface being smooth and level, like an artificial floor stretched across the valley. Above, and on the right and left of this dazzling carpet, arise hundreds of nameless peaks, seeming to pierce the skies, whose azure hue is so intense as to find no match in nature, save the gentian, which often expands, in all its beauty, close to the perpetual snow of the glacier.

The sides, scathed by lightning and torn by the avalanche, scarcely permit a resting-place for the snow, which accumulates in dazzling wreaths only in its sheltered

nooks Each of these pinnacles, transported to an ordinary scene, would seem one of nature's grandest objects; but here it is lost amidst the crowd of its fellows. But a few of them have any specific names, and still fewer are to be found indicated on the most accurate maps of the Alps.

The structure and consistence of this part of the glacier, are very remakable. It is evidently snow, in the act of passing into ice, having a granular structure, resulting from the partial thaw to which it has been subjected. On the flanks of the mountains, and even on their summits, the snow is often consolidated into a compact icy structure, alternating, however, in the more sheltered places, with crisp snow, which separates the icy layers, characteristic, also, of the proper névé.

That true ice should be found on the highest summits, and above what is considered the line of perpetual congelation, is not a matter of surprise to those who reflect that the sun acts at these elevations, with an intensity unknown below; and although the continued accumulation of snow is no doubt mainly prevented by the action of wind, (which may be seen driving to leeward a delicate cloud of snowy particles, having all the appearance of the finest vapor,) and likewise by the *immediate* evaporation of the snow, without passing into water; yet there can be no question that every hot summer's day fuses a portion of the snow, which is turned into ice the succeeding night, forming a true icy crust on the most insulated summits, where the snow can find a resting-place.

Sometimes these icy crusts accumulate in thickness by the accession of new falls of snow, so as to project several feet over the most awful precipices. This crust, pierced or broken inadvertently, may bring the unwary pedestrian into the most perilous situation, or even sacrifice his life. M. Hugi describes such an instance in his own case. While attempting to ascend the Finster Aar Horn, he broke, by his weight, through a cornice of ice, such as we have described, only two feet thick, and projecting over a sheer precipice of 4,000 feet, or more than three-fourths of a mile in depth. Fortunately, at this awful moment, one of his companions had, for security, taken hold of a long staff which Hugi carried in his hand; and now, the footholds of both giving way, they were suspended, each at the end of the pole, in frightful equilibrium, as at the

arms of a balance, until their guides providentially came to their rescue.

686. *Gravel cones.*—We have already seen that the glaciers bear on their surfaces quantities of broken stone, of various sizes, the products of disintegrated mountains, which have been precipitated from their resting-places by the winter's frost, or the summer's avalanche. In addition to this detritus, many glaciers are covered with a number of gravel cones, whose sizes and regularity astonish and perplex the beholder. Some of them are 15 or 20 feet in height, and 70 or 80 feet in circumference. At first sight, no one would doubt but these are solid heaps of sand. In shape and appearance, they resemble enormous ant-hills; and while the spectator is curious to know how it is possible for such objects to obtain such a place, his wonder is raised at the fact, that sand and gravel could possibly retain such a shape. But, on further examination, he finally arrives at the no less marvelous truth, that what he mistook for heaps of sand, are solid ice, within a small distance under their surfaces. The manner in which they are formed, appears to be this: Suppose a heap of sand, a few feet, or more, high, poured on a flat surface of ice. During the summer, the sun melts the ice in all directions, except where it is protected by the sand, and thus in effect the sand rises, while the surrounding ice sinks, and this being continued, year after year, a cone of ice is formed within, being protected and covered by the sand without.

687. *Theory of the movement of glaciers.*—While all attentive observers agree that the glacier has a motion down the side of the mountain, and sometimes in its lower part, even on a level plain, there is much diversity of opinion with respect to the cause of this movement; nor can this excite our surprise, since this cause, whatever it may be, is so secret and silent, that even the effect cannot be detected without careful observation.

The most voluminous and able writer on this subject M. Agassiz, attributes this motion to the expansion of the glacier itself, this expansion being caused by the infiltration of water into the ice and snow, during the summer, and the freezing of the same during the winter. The expansion of water, in the act of freezing, is considerable; and, it is well known, exerts a force equal to the bursting

of heavy cannon. It is true that this force acts in every direction; but it must be remembered that, in the present case, the upper end of the ice rests against the side of the mountain; and, therefore, that there is a barrier to its motion in that direction, so that the movement must be downward, if at all. Now, were the motion of the glacier owing to this cause alone, it ought to take place only at the beginning of winter, or at the time when the water is converted into ice; for, after this, the expansion ceases. It is, however, true, that during the cold of winter, the frost reaches deeper and deeper into the ice, so that this force, though at first only exerted at the surface, finally reaches many feet, or even yards, into the mass. This expansion below, would of course occasion fissures, by the cracking of the ice at the surface, which accordingly are found in all the glaciers. Sometimes, however, they are several hundred feet deep, and, therefore, must be due to other causes than the percolation and freezing.

Professor Forbes, a recent writer on the subject, who, it appears, has spent ten summers among the Alps, denies that the motions of the glaciers are due to the expansion of the water, by freezing; for, *first*, the water percolates to but a small distance during the summer; *second*, were this the true theory, the motion ought to be greatest during winter; *third*, the motion is much greater during the summer-thaws than at any other season. Former writers supposed the motion was owing to gravity, there never being such an attachment by frost, between the ice and the ground, or rocks, as to prevent a sliding movement down the mountain. On the contrary, it is said the glacier moves even where the declivity is very slight, the inclination being no more than five degrees, or not so great as to prevent a loaded team from passing up it.

688. *What is a glacier?*—To this question, Professor Forbes answers: "A snow-clad mountain is not a glacier. The common form of a glacier, is a river of ice, filling a valley, and pouring down its mass into valleys still lower. It is not a frozen ocean, but a frozen torrent. Its origin, or fountain, is in the ramification of the higher valleys and gorges, which descend among the mountains, perpetually snow-clad. But what gives a glacier its most peculiar and characteristic feature, is, that it does not belong exclusively, or necessarily, to the snowy region. The

snow disappears from its surface in summer, as regularly as from that of the rocks that sustain its mass. Its gelid masses protrude into the midst of warm and pine-clad slopes and green sward, sometimes reaching to the borders of cultivation. The very huts of the peasantry are sometimes invaded by this moving ice, and many persons now living, have seen the full ears of corn touching the glacier, or gathered ripe cherries from the tree, with one foot standing on the ice."

Such being the nature and phenomenon of the glacier, Prof. Forbes, after examining and setting aside the chief previous theories, announces his own, as follows:—"*A glacier is an imperfect fluid, or a viscous body, which is urged down slopes of a certain inclination, by the mutual pressure of its parts.*"

It is, therefore, the gravity of its own mass, by which it is urged forward, and this he illustrates by such examples as melted tar, mortar and treacle, moving down an inclined plane, which is steep at the part where the motion commences, but gradually diminishes, until it becomes nearly level, where the motion ends, this being the form of most glacier-beds.

Considering the semi-fluid consistence of the mass, which other writers have not insisted on, Prof. Forbes' theory, we think, best accounts for the phenomena in question. It is, in fact, a gelatinous mass, but sufficiently fluid to observe the same laws as running water, moving faster in warm weather than in cold—the centre flowing more rapidly than the sides, and the top faster than the bottom, owing to these portions being retarded by friction.

M. Agassiz supposes that large tracts of country were anciently covered with glaciers, and in that manner accounts for those immense accumulations of stones which have so long puzzled geological inquirers, and which some have supposed that the deluge swept together. Since this theory has been published, geological appearances have been explained, which before were a mystery in many parts of the world. In Scotland, Ireland and England, accumulations of stones and rocks, before unaccountable, are now seen to be *moraines*, and in this country the same theory very satisfactorily accounts for the same facts.

CHAPTER XLVIII.

FOSSIL HUMAN BONES:

WHERE FOUND, AND WHETHER ANCIENT OR RECENT.

589. *Important question in geology.*—The question whether any human remains have been found in ancient strata, has been matter of controversy among naturalists, during at least the last half century. Before this period, and when even the professors of anatomy knew very little of comparative osteology, there was no want of what were believed to be human bones. Even those of the mastodon, as already stated, were sent from this country to London, as the bones of giants. But since Cuvier, and others, have made fossil remains an important object of study, such discoveries have been less common. Still, the remains of human beings, where no doubt exists of their identity, have been frequently discovered in caves, with the bones of extinct animals; and also in calcareous deposits.

590. *Cavern of Durfort.*—This cavern is in France, and is situated in a hill about 500 feet high. It consists of several chambers, or apartments, with narrow passages leading from one to the other, the last of which, being about three yards square, contains the human bones. They lie in the utmost confusion, in the paste or matter which unites them; and are in such numbers, as to form half the bed on the floor of the cavern. A great number is also united to the rock, by calcareous incrustations. They are chiefly those of the head, thigh, and arms, and most of them belonged to adults of men and women, and some also to children.

M. de Serres, who makes this statement, says that the narrowness of the passage is an invincible objection to the bodies, to which these remains belonged, being carried there after death. The people in the vicinity have a tradition, that at some remote period, they were brought from a distance, and deposited there. They are not completely mineralized, or petrified, but still retain some portion of [illegible] matter. This latter circumstance is considered a [illegible] proof that they are not of high antiquity; and,

therefore, might have been deposited there within a few centuries.

LIGN. 123.

Human skeleton at Guadaloupe.

691. HUMAN REMAINS AT GUADALOUPE.—The limestone of Guadaloupe, celebrated all over the geological world, and mentioned in every book on fossils, during the last half century, is the only place where human remains have been found imbedded in solid rock. This seems to have been formed, and is said to be still forming, in the following manner:

692. *Mode of formation.*—The coral reefs, which surround the island, are worn and abraded by the incessant action of the waves, and the detritus thus occasioned, is washed to the shore in the state of coralline sand, or mud, where, by the action of the atmosphere, or streams holding carbonate of lime in solution, the mass becomes indurated into a compact limestone. It is quite evident that the rock was in a soft and yielding state when these skeletons were imbedded in it; and it is also ascertained that the bones are not fossilized, but retain their animal matter, as gluten and phosphate of lime. The modern origin of the rock is also proved by its containing land-shells, frag-

ments of pottery, stone arrow-heads, and carved wooden ornaments.

693. *The skeletons.*—The bones, in most instances, are separated and dispersed, probably by the action of the waves; but, in one instance, a large slab was raised up, which contains imbedded in it, a considerable proportion of a female skeleton. This is now in the British Museum, and is here represented by *Lign.* 123. This celebrated relic embraces the chief parts of the human skeleton, with the exception of the head and feet, the whole being fastened to the slab of limestone, or rather partly imbedded in it, by the calcareous matter of which the rock itself is formed.

694. *The skull.*—It is, perhaps, a remarkable fact, that the head of this very specimen, now belongs to the museum of the Medical College in South Carolina, having been purchased of a French naturalist, who procured it at Guadaloupe. It has been examined by Prof. Moultrie, of that College; who, as stated by Dr. Mantell, pronounces it to be a skull belonging to one of the Peruvian races. This, however, does not agree with the tradition of its origin, which is as follows: Gen. Erneuf, a French military officer, having examined all the circumstances within his reach, concerning this famous deposit, ascertained that there had been a battle near this spot, between two tribes of the former natives of the island, about 130 years ago; and it was conjectured that the bodies of the slain had been interred near the shore; the skeletons afterwards having been imbedded by the water, which converted the sand into solid rock, by the deposition of calcareous matter.

695. *Other skeletons from the same place.*—Many human bones have been found at this locality, but most often in detached parts, or fragments. There is, however, in *Cuvier's Theory of the Earth*, a description or figure of a human skeleton, from Guadaloupe. It is not entire; the head, feet, and some other parts, being absent. This appears to have been buried in the sitting posture. It is still preserved in the Museum of the Garden of Plants in Paris.

696. *Human body found at Gibraltar.*—The following is from the *United States Literary Gazette*, and appears to bear the marks of truth, though not the language of science:

In March, 1845, the Chief Justice of Gibraltar, while making repairs about his house, had occasion to dig near the foundation. and while thus engaged, one of the work-

men discovered a deep fissure in the rock. Into this the Chief Justice, and several of his men, ventured; and after having descended about 40 feet, nearly in a perpendicular direction, came to a narrow passage, which led to a most beautiful cave, where stalactites were hanging in abundance, some of them as white as snow, and in the shape of cauliflowers. In the midst of this was a human skeleton, sticking fast to the rock, and the bones of a dog beside those of his master. The Chief Justice's house, which is an old one, is immediately over the cave. I walked out on the 4th instant, to examine these bones. It is quite melancholy to see the skull; the water has dropped down on the lower jaw, and, there leaving the lime it contained, has given it the appearance of a beard.

Some parts appear to be entirely petrified; but the scalp still remains, and the veins on the left side are quite distinct. This part is turned into stone, or is covered by the stalactite, which is chipped off here and there, down to the bone of the skull, which is white, like ivory. The nose, likewise, has not decayed, but the parts about it are also stone. The bones of the right hand were fastened to the right side of the head; so that the poor creature has the appearance of having laid down and died, very probably, by starvation, with his hand under his head, which is half turned round, as if he, or she, had been looking up. The entire set of teeth were beautifully perfect; but the front ones of the lower jaw dropped out when it was moved. There is some of the back-bone, arm-bones, ribs, and thigh; in fact, I believe they have them all complete. The bones of the dog lay beside the human bones.

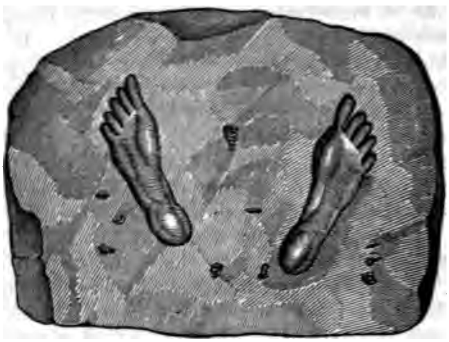
REMARKS.—This discovery will not at all surprise those who are aware that the rock of Gibraltar is a cavernous limestone, and that several fissures and apartments, containing stalactites, have been long known to the inhabitants, and are shown to strangers as geological wonders. This appears to have been a newly-discovered fissure, into which some unfortunate man and his dog had been precipitated; and there having perished, the remains were covered with stalactical lime, (347,) from the dripping of the water.

IMPRESSIONS OF HUMAN FEET IN SANDSTONE.

697. "In connection with the occurrence of human bones in limestone," says Dr. Mantell, "I will here notice

a discovery of the highest interest, but which has not yet excited, among scientific observers, the attention which its importance demands. I allude to the fact announced in the *American Journal of Science*, (vol. v. for 1822,) of impressions of human feet in sandstone, discovered many years ago, in a quarry at St. Louis, on the western bank of the Mississippi.

LIGN. 124.



Impressions of human feet in sandstone.

698. "The above Lignograph is an exact copy of the original drawing, and exhibits the impressions of the soles of two corresponding human feet, placed at a short distance from each other, as of an individual standing upright in an easy position. The prints are described as presenting the perfect impress of the feet and toes, exhibiting the form of the muscles, and the flexures of the skin, as if an accurate cast had been taken in a soft substance."

"They were at first supposed to have been cut in the stone, by the native Indians; but a little reflection sufficed to show that they were beyond the efforts of those rude children of nature; since they evinced a skill, and fidelity of execution, which even my distinguished friend, Sir Francis Chantrey, could not have surpassed. No doubt exists in my mind, that they are the actual prints of human feet in soft sand, which was quickly converted into solid rock, by the infiltration of solid matter. The

length of the foot is ten inches and a half; the spread of the toes four inches, indicating the usual stature; and the nature of the impression shows that the feet were unconfined by shoes or sandals."—*Wonders*, p. 77.

These foot-prints, as we see from the above marks of interest in the mind of Dr. Mantell, created quite a sensation among geological inquirers; but on more close examination of the prints themselves, and inquiry into the circumstances, it is now believed that they are not natural, but artificial marks, made by a stone-chisel, or some other instrument.

CHAPTER XLIX.

COINCIDENCE OF GEOLOGY WITH THE MOSAIC HISTORY.

699. *Attempts to show that Moses and geology disagree.*—Almost from the commencement of geological investigations, designing men have attempted to show, that the physical history of the earth, by geologists, and the Scripture history of the creation by Moses, could not be reconciled; that the former presented facts, which were incompatible with the latter; and that, therefore, revelation and reason were in opposition to each other.

700. *The church looked with jealousy on this subject.*—Hence it was, that in the early history of this science, the church looked with jealousy upon these investigations, and even went so far as to restrict philosophers in their pursuits, or, at least, in their publications, and to denounce those who pretended to make discoveries, which they could not reconcile with the Mosaic record.

701. *Time was wanted.*—Judging from the effects of causes now in operation on the surface of the earth, it was supposed impossible that the deep strata found in many places could have been formed within the narrow period assigned by the sacred history. The whole earth, indeed, seemed to bear such marks of antiquity, as could not be reconciled with any hypothesis of its recent origin. *Time* was therefore wanted; for the cosmogonist found that it was impossible to bound his speculations within the con-

fined limits allowed by Moses. It was consequently necessary that he should either come out boldly, and deny that authority, or invent some new interpretation of the text, by which the scope of his retrospective vision should be free and unbounded.

702. *Whiston's proposition.*—In this dilemma, the celebrated theorist Whiston, in 1696, proposed that the book of Genesis should be so interpreted as to allow geologists full scope for their cosmogonies, without being suspected of heretical opinions; and thus were the Scriptures made to bow down before geology.

703. *The church at the present day have no fears of geology.*—It must be remembered that it was in the infancy of geology, that the ministers of religion were afraid that such investigations would encourage infidelity, by the discovery of facts which could not be explained so as to accord with Scripture history. At the present time, when geology is reduced to a regular and important science, and when the progress of discovery, in its several branches, is not only seen with approbation by Christian philosophers, but its investigations are carried on by men of superior minds and attainments, including many of the sacred profession, there is no longer any fear that the structure of the earth, when described by learned and sincere men, will appear in collision with the history of the creation, or that science and religion will not harmonize in all their relations.

704. *Dr. Buckland on the consistency of geology and the Scriptures.*—"It would seem just matter of surprise, that many learned and religious men should regard with jealousy and suspicion the study of any natural phenomena, which abound with proofs of some of the highest attributes of the Deity; and should receive with distrust, or total incredulity, the announcement of conclusions, which the geologist deduces from careful and patient investigations of the facts which it is his province to explore. These doubts and difficulties result from the disclosures made by geology, respecting the lapse of very long periods of time before the creation of man. Minds which have long been accustomed to date the origin of the universe, as well as that of the human race, from an era of about six thousand years ago, receive reluctantly any information, which, if true, demands some new modification of their present ideas of cosmogony; and as, in this respect, geol-

ogy has shared the fate of other infant sciences, in being for a while considered hostile to revealed religion; so like them, when fully understood, it will be found a potent and consistent auxiliary to it, exalting our conviction of the power, and wisdom, and goodness of the Creator."—Bd. p. 18.

705. *No discrepancy between the words, and the works of God.*—"No reasonable man can doubt that all the phenomena of the natural world derive their origin from God; and no one who believes the Bible to be the word of God, has cause to fear any discrepancy between this, his word, and the results of any discoveries respecting the nature of his works; but the early and deliberate stages of scientific discovery are always of perplexity and alarm, and during these stages, the human mind is naturally circumspect, and slow to admit new conclusions in any department of knowledge. The prejudiced persecutors of Galileo apprehended danger to religion from the discoveries of a science, in which a Kepler and a Newton found demonstrations of the most sublime and glorious attributes of the Creator."—Bd. p. 19.

706. *Inspiration and nature do not differ.*—Now, we have the satisfaction of believing, with Dr. Buckland, that the systems of inspiration and nature have both emanated from the same divine authority, and that, when both are rightly understood, they will coincide with each other; and it will be our object to show, in the following pages, that even taking the Scriptures in their most obvious meaning, there is still no want of harmony between them and natural phenomena—at least so far as relates to geology and the Mosaic history.

CREATION OF HEAVEN AND EARTH.

707. *Genesis* i. 1.—"In the beginning, God created the heaven and the earth."—That is, in the beginning of *time*, the earth was created; for, before this creation, there was nothing by which time could be measured: all was eternity.

708. *This creation distinct from what follows.*—The terms here employed, and the full period which the sentence requires, seem to indicate that the language is intended to show that the creation here referred to, had no connection with what follows.

The creation of the heaven and the earth must there-

fore, we think, be considered a separate and independent act, from those which afterwards set the sun and moon in their places, and called into existence the beings by which the earth was inhabited.

709. *We know nothing of the period of this creation.*—How long before the six days' work, described by Moses, the heavens and the earth were created, we are not informed, and, therefore, all speculation on this point is useless. Had it been important for man to know the distance between these two periods, it would have been communicated to the historian, and recorded for his benefit. All the knowledge we possess concerning this period is, that it extends from the "beginning," down to the time when God said "Let there be light;" this being the first act of creation described by Moses.

710. *Ample time here for geological speculations.*—From the "beginning," therefore, down to the creation of the sun, we see no reason why geologists may not take the advantage of an indefinite period of time, without encroaching in the least on Scripture authority. Instead of considering a Mosaic day—that is, from morning to evening—a time of indefinite length, and thus making six indefinite periods, as some geological writers have done, we see here no difficulty in obtaining a period of sufficient length for the speculations of any world-maker, and that, too, by at least negative Scripture authority, provided his retrospective vision does not extend beyond the "beginning."

711. VERSE 2. "The earth was without form and void, and darkness was upon the face of the deep."

The meaning of this verse appears to be, that from the beginning—that is, from its creation down to the time of Moses—the earth had been in a dark and unformed, or chaotic state. It had not been brought into a condition fit for the residence of man, and other animals. It was probably in total darkness, for the light had not yet been called into existence. It appears also to have been surrounded by water, since the "*deep*" (that is, the sea, not the earth,) is spoken of.

712. VERSE 3. "And God said, Let there be light; and there was light:" in Hebrew, "light was."

Whence did the first light emanate.—This is the first act of creation in the series afterwards described by the historian, and various opinions have been advanced concerning the nature of this light, and the source whence it pro-

ceeded. Some have supposed that it was electrical, and others phosphorescent; and, in either case, that it did not emanate from a fixed point, but that it was diffused through the space surrounding the earth. Others have ascribed it to a meteor, which was created for the purpose of enlightening the earth during the first three days, and before the sun was created. But there is neither authority nor analogy for such a supposition; and it would even be derogating from the wisdom and power of Him who, three days after, set the great lights in the firmament, to believe that He should have created an evanescent one, for the use of the earth, while as yet it contained neither plant nor animal.

VERSES 4, 5. "And God divided the light from the darkness." "And the evening and the morning, were the first day."

713. *The light must have come from a fixed point.*—Whatever might have been the source whence this light came, it is evident, *from* this declaration, that it could not have been generally diffused around the earth; for had this been the case, it is impossible for us to comprehend how it could have been divided from the darkness. On the contrary, the terms of the record leave no doubt that at this time the earth had already commenced her diurnal revolutions; and the light, emanating from a fixed point, the sun, was divided from the darkness, by the first succession of day and night. This is, in truth, affirmed by what next follows: "And God called the light *day*, and the darkness he called *night*."

714. VERSE 6. "And God said let there be a firmament in the midst of the waters, and let it divide the waters from the waters."

The meaning of firmament.—The original Hebrew word means *expansion*. It is *rakaiah*, which comes from a root, signifying *to stretch out*, or *expand like a curtain.—Bush on Genesis.*

VERSE 8. "And God called the firmament heaven."

It is apparent that Moses intended to adapt his account of the creation to unlettered common sense, and to describe natural events as they would have struck the eye of a common observer, had he been present at the creation, and witnessed the several events. Hence, the firmament is called *heaven*, because it is placed over our heads; and for

the same reason, the sun, moon, and stars, are said to be placed in the firmament. Now, heaven, as the word is here employed, means nothing more than the blue vault of the sky, and therefore is synonymous with firmament. Firmament is the atmosphere which we breathe, and which, science has taught us, reaches to the height of about 45 miles, from every part of the earth's surface.

Now, the stars are millions of miles beyond this firmament; but since they are seen *through*, they appear to us to be placed *in* it, and the Mosaic history is adapted to this illusion.

VERSE 7. "And God made the firmament, and divided the waters which were under the firmament, from the waters which were above the firmament."

715. *Water absorbed by the atmosphere.*—By this act, the atmosphere was made to absorb a part of the waters which had previously surrounded the earth, and thus to elevate them above its surface. The quantity of moisture contained in the atmosphere, differs greatly in different countries, and at different times; but that it is capable of elevating large quantities of water, is sufficiently proved by the profusion of rain which falls from it to the earth.

The atmosphere is incapable of absorbing any of the solid ingredients with which the water on the earth, or in the sea, is mixed; a striking mark of design, for were the salt of the sea, as well as many light materials of the earth, taken up with the water, and sent down in the form of rain, not only most of the vegetable kingdom would be destroyed, but also all terrene animals.

716. VER. 16–18. "And God made two great lights, the greater light to rule the day, and the lesser light to rule the night; he made the stars also." "And set them in the firmament of the heaven, to give light upon the earth, and to rule over the day."

This was the fourth day's work.

717. *Difference between "made" and "create."*—The original of the word *made*, is not the same with that rendered *create*. The latter term signifies *reform*, or *renovate*, while the former more often implies *constituted*, or *set apart*.—*Bush on Genesis.*

Sun and moon made to appear.—The language does not, therefore, necessarily imply, that the sun and moon were *created* on the fourth day, but only that they were made

to *appear*, and act as rulers over the day and night, at that time. If we believe that Moses stated the story of the creation, as it would have appeared to human eyes at the time, as already supposed, these luminaries would, undoubtedly, have seemed a new creation; when, in truth, they might have existed from the instant when God said, "Let there be light."

718. *Earth surrounded with vapors.*—We infer that the sun might have existed, without being seen, from the circumstance that the newly-renovated earth must have been surrounded with dense vapors, since, until the third day, when the land appeared, the atmosphere rested on a continuous ocean of water. The *mist*, spoken of afterwards, shows that the earth supplied the atmosphere with abundance of moisture, for some time after the land appeared. Hence, there is nothing to prevent the supposition, that the clouds of moisture prevented the sea from being seen until the fourth day, when these were condensed or swept away, and the sun shone, for the first time, in all his glory; and, to a witness of the circumstances, this would have appeared as a new creation. It is, therefore, not incompatible with the terms of the history, to believe that when God said, "Let there be light," the sun came into existence, though it did not shine upon the earth until the fourth day.

719. *Signs, seasons, days and years.*—Besides dividing the light from the darkness, and ruling the day, the sun and moon were to be for "for signs, and for seasons, and for days, and years."

The seasons.—The vicissitudes of the seasons are caused by the revolutions of the earth around the sun, together with the obliquity of the earth's axis. It is, therefore, well known that it is by the real motion of the earth around the sun, instead of the apparent motion of the sun, that the changes are produced. The language, however, is in conformity with that employed in the other parts of the history, the appearances being described without reference to their real causes.

720. *The word "day."*—That the historian here meant, by the word *day*, the time included between two settings of the sun, or a period which we call 24 hours, instead of an indefinite period, as some have claimed, for the days of creation—that by the word *seasons*, he meant

the common seasons of the year; and that by this term was signified from spring to spring again, we believe no one will deny, who desires to give the Scriptures a fair and honest interpretation.

721. VERSE 20. "God said, Let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth in the open firmament of heaven."

722. *Creeping instead of moving.*—Commentators say that this is often rendered *creeping*, instead of *moving* creatures. The word is said to be derived from a verb, which signifies to bring *forth abundantly*, so that the translation ought not to be *creeping*, but the *rapidly-multiplying* CREATURES.

The meaning is obviously intended to include the larger reptiles, as well as all the small animals inhabiting the sea, as insects, worms, and shell-fish, many tribes of which are known to be exceedingly prolific.

723. *Creation of the mammalia and man.*—On the sixth and last day of the creation, the beasts of the earth, cattle after their kind, and lastly *man*, were brought into existence. The "beast," and "cattle," are supposed to include that whole class of the animal kingdom, now called mammalia, or milk-giving quadrupeds, the amphibious quadrupeds having been created on the fifth day.

MOSAIC AND NATURAL SYSTEMS OF PLANTS.

724. It is a singular and remarkable fact, we believe not hitherto noticed by any writer, that there is a striking coincidence between the divisions of the vegetable kingdom, as described by Moses, and the most perfect natural systems of Botany of the present day.

After the earth was prepared for vegetation, "God said, Let the earth bring forth grass, the herb yielding seed, and the fruit-tree yielding fruit after his kind, whose seed is in itself, upon the earth; and it was so."—*v.* 11.

Instead of grass, the Hebrew means *tender*, or *budding*-grass, or grass *sprouts*, (marginal reference,) thus apparently intending to include all the small, or inferior plants, with which the earth is clothed, and which, to common observation, spring up without seeds, or are propagated by the roots. Many low plants, of the moss tribes, also bear capsules, which appear like buds, (*budding-grass*,) though

they produce no flowers or visible seeds; and these, in popular language, would come under the general denomination of "grass."

725. CRYPTOGAMIA.—The terms, therefore, warrant us in the conclusion, that in this division, the author intended to embrace generally, those plants which give verdure to the fields, but whose seeds were concealed, or not apparent, and thus to distinguish them from the herb-yielding seed, or those whose seeds form the most obvious part of the plant. This division would, therefore, embrace those tribes now known by botanists under the title of Cryptogamous, or flowerless plants, (61.)

726. MONOCOTYLEDONS.—The "herb-yielding" seed, by the most obvious construction, applies to the grand natural division of plants, now called Monocotyledonous, or such as produce seed with a single lobe, (63,) as *wheat*, *barley*, *broom-corn*, *rye*, *millet*, &c. Hence, "seed-yielding plants" would be a very obvious and natural distinction of this order, the seeds themselves being the most conspicuous part of the plants, and would most readily separate them from the cryptogamia, where no seeds are to be seen.

727. DICOTYLEDONS.—"The tree yielding fruit, whose seed is in itself," that is, in the fruit, is a description which clearly proves a third grand division of the vegetable kingdom. This division was, undoubtedly, intended to include the larger vegetables or trees; and the description applies with singular accuracy to many of the most common fruit-bearing plants in all parts of the world. The *apple*, *pear*, *peach*, *almond*, *grape*, *bread-fruit*, *orange*, *chestnut*, *oak*, *bean*, *pea*, and many other domestic, as well as forest plants, which, from the most ancient times, have been known, and most highly esteemed, bear their seeds within their fruits, and are thus naturally distinguished from wheat, barley, oats, and other plants of this kind, where the seeds are apparent to the sight. This division, therefore, corresponds to the present class in natural botany, called dicotyledonous, (64,) or plants with two seed-lobes, and which class includes many of the most important vegetables in every temperate climate.

628. CONCLUSION.—Thus do we arrive at the most remarkable, and, indeed, surprising fact, which we believe no naturalist has before noticed, that the three grand divisions of the vegetable kingdom, made by the Scrip-

tures, not only bear analogy to the most improved natural system of botany at the present day, but that the two systems are, in the outline, identical; and it is worthy of notice, that the existence of this analogy is owing to the perfection to which natural botany has been brought, by the recent investigations of profound naturalists.

Thus do philosophers, unawares, confirm the inspiration of the Holy Scriptures; for there is not the slightest probability that the system of Moses could have been founded on any practical knowledge of botany, at least as a system; and, therefore, such an arrangement could not have been derived from any human source.

DAYS OF CREATION.

We have already noticed that some geological writers have proposed to gain time for the formation of stratified rocks, by extending the days of creation to indefinite periods. It is believed that no one will deny, that whatever may be said of the prophecies, the *narratives* of the Old Testament were intended, by their authors, to be understood by ordinary capacities; nor will it be claimed that the author of Genesis has been so inconsistent with himself, as, on that account, to raise a suspicion of his veracity.

If an author uses the same terms in different places, and apparently in the same sense, we are bound to believe that he means the same thing in every case. If he intends to convey different ideas by the same terms, standing in similar connections, and this without warning his readers, he cannot be a correct writer, because he is not only inconsistent with himself, but cannot be understood.

Now, in applying these propositions to the author of Genesis, we there find that in his narrative of the work of creation, he states that the whole was performed in *six days*, each day's work being described by itself, and every day carefully numbered, that in so important a work, there should be no doubt with respect to the succession of the several creations, or the time when the whole was finished.

The same author has also written a narrative of the destruction of the ancient world by a flood of water. In this he states that "the flood was forty *days* upon the earth;" or, that it rained forty days, and that "the waters prevailed upon the earth an hundred and fifty *days*."

Now, these historical events being from the same pen—being also in connection, as parts of the same general history, and the word *day*, being employed in the same unqualified manner in both—no reader can doubt, if the common translations convey the meaning of the historian, that *he* intended that the same word should be understood to signify the same period of time in both narratives.

From the statements of Moses, therefore, we are as fully entitled to the belief, that the waters of the deluge prevailed upon the earth for an indefinite period, or, that a day of the deluge was a thousand years, and thus, that its waters covered the earth for the term of 150,000 years, as we are to believe that a day of the creation was a period of 1,000 years, and thus that 6,000 years were occupied in the work of creation.

Besides, if these days were periods of 1,000 years, how can it be said that the sun and moon were to be "for signs, and for seasons, and for day, and years;" and what must the author have understood the length of these several periods to be?

Again: "Six days shalt thou labor, and do all thy work, but the seventh day is the sabbath of the Lord thy God; in it thou shalt not do any work." "*For* in six days the Lord made heaven and earth, the sea, and all that in them is, and rested the seventh day. Wherefore, the Lord blessed the sabbath day, and hallowed it."—*Ex.* xx.

No one will deny that this commandment was expressly founded on the fact, that the work of creation, described by Moses, was finished in six days, and that this commandment was to be in imitation, and perpetual commemoration of that event. "Six days shalt thou labor, and do all thy work." "*For* in six days the Lord made heaven and earth."

Now, Christians universally believe that this commandment was meant, by the Creator, to enforce on them the duty of resting from their labors every seventh day, in commemoration of his example, after the work of the creation. But we would inquire of those who contend that geology makes it necessary to extend these days to 1,000 years, how men, with lives of only three score and ten years, can fulfil this commandment?

Besides, do we not impudently derogate from the almighty power of Him who "spake, and it was done?"

who said, "Let there be light, and light was?" and "who created all things by the word of his power," by supposing that such a God was occupied thousands of years in creating this little earth, and the beings which inhabit it? If the stars are suns to other planetary systems, what a mote our world must be, in comparison with the whole! And yet the Creator of the "heavens and the earth," no doubt, had the power of bringing the whole into existence in an instant of time. Otherwise, His power could not have been infinite and almighty. Is it not, then, a virtual denial of His wisdom and strength, to declare that the structure of the earth shows that thousands of years were occupied in doing what the same power might have done in a moment?

GLOSSARY

OF

GEOLOGICAL AND OTHER SCIENTIFIC TERMS USED IN THIS WORK.

FROM LYELL'S PRINCIPLES OF GEOLOGY.

Acephalous. The Acephala are that division of molluscous animals which, like the oyster and scallop, are without heads. The class Acephala of Cuvier comprehends many genera of animals with bivalve shells, and a few which are devoid of shells. *Etym.*, *a*, *a*, without, and κεφαλη, *cephale*, the head.

Acidulous. Slightly acid.

Adipocere. A substance apparently intermediate between fat and wax, into which dead animal matter is converted when buried in the earth, and in a certain stage of decomposition. *Etym.*, *adeps*, fat, and *cera*, wax.

Albite. *See* "Feldspar."

Alembic. An apparatus for distilling.

Algæ. An order or division of the cryptogamic class of plants. The whole of the sea-weeds are comprehended under this division, and the application of the term in this work is to marine plants. *Etym.*, *alga*, sea-weed.

Alluvial. The adjective of alluvium, which see.

Alluvion. Synonymous with alluvium, which see.

Alluvium. Earth, sand, gravel, stones, and other transported matter, which has been washed away and thrown down by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas. *Etym.*, *alluo*, to wash upon, or *alluvio*, an inundation.

Alum-stone, Alumen, Aluminous. Alum is the base of pure clay, and strata of clay are often met with containing much iron-pyrites. When the latter substance decomposes, sulphuric acid is produced, which unites with the aluminous earth of the clay to form sulphate of alumine, or common alum. Where manufactories are established for obtaining the alum, the indurated beds of clay employed are called Alum-stone.

Ammonite. An extinct and very numerous genus of the order of molluscous animals called Cephalopoda, allied to the modern genus Nautilus, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata; but they have not been seen in the tertiary beds They are named from their resemblance to the horns on the statues of Jupiter Ammon.

Amorphous. Bodies devoid of regular form. *Etym.*, *a*, *a*, without, and μορφη, *morphe*, form.

Amygdaloid. One of the forms of the Trap-rocks, in which agates and simple minerals appear to be scattered like almonds in a cake. *Etym.*, αμυγδαλα, *amygdala*, an almond.

Analcime. A simple mineral of the Zeolite family, also called Cubizite, of frequent occurrence in the Trap-rocks.

Analogue. A body that resembles or corresponds with another body. A recent shell of the same species as a fossil shell is the analogue of the latter.

Anoplotherium. A fossil extinct quadruped, belonging to the order Pachydermata, resembling a pig. It has received its name because the animal must have been singularly wanting in means of defense, from the form of its teeth and the absence of claws, hoofs, and horns. *Etym.*, ανοπλος, *anoplos*, un armed, and θηριον, *therion*, a wild beast.

Antagonist Powers. Two powers in nature, the action of the one counteracting that of the other, by which a kind of equilibrium or balance is maintained, and the destructive effect prevented that would be produced by one operating without a check.

Antennæ. The articulated horns with which the heads of insects are invariably furnished.

Anthracite. A shining substance, like black-lead; a species of mineral charcoal *Etym.*, ανθραξ, *anthrax*, coal.

Anthracotherium A name given to an extinct quadruped, supposed to belong to the Pachydermata, the bones of which were first found in lignite and coal of the tertiary strata. *Etym.*, ανθραξ, *anthrax*, coal, and θηριον, *therion*, wild beast.

Anthropomorphous. Having a form resembling the human. *Etym.*, ανθρωπος, *anthropos*, a man, and μορφη, *morphe*, form.

Antiseptic. Substances which prevent corruption in animal and vegetable matter, as common salt does, are said to be antiseptic. *Etym.*, αντι, *against*. σηπω, *sepo*, to putrify.

Arenaceous. Sandy. *Etym.*, *arena*, sand.

Argillaceous. Clayey, composed of clay. *Etym.*, *argilla*, clay.

Arragonite. A simple mineral, a variety of carbonate of lime, so called from having been first found in Arragon, in Spain.

Atolls. Coral islands of an annular form, or consisting of a circular strip or ring of coral surrounding a central lagoon.

Augite. A simple mineral, of a dark green, or black color, which forms a constituent part of many varieties of volcanic rocks. Name applied by Pliny to a particular mineral, from the Greek αυγη, *auge*, lustre.

Avalanches. Masses of snow, which, being detached from great heights in the Alps, acquire enormous bulk by fresh accumulations as they descend; and when they fall into the valleys below, often cause great destruction. They are also called *lavanges*, and *lavanches*, in the dialects of Switzerland.

Basalt. One of the most common varieties of the Trap-rocks. It is a dark green or black stone, composed of augite and feldspar, very compact in texture, and of considerable hardness, often found in regular pillars, of three or more sides, called basaltic columns. Remarkable examples of this kind are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from *basal*, an Ethiopian word, signifying iron. The rock often contains much iron.

"Basin" of Paris, "Basin" of London. Deposits lying in a hollow or trough, formed of older rock; sometimes used in geology almost synonymously with "formations," to express the deposits lying in a certain cavity or depression in older rocks.

Belemnite. An extinct genus of the order of molluscous animals, called Cephalopoda, having a long, straight, and chambered conical shell. *Etym.*, βελεμνον *belemnon*, a dart.

Bitumen. Mineral pitch, of which the tar-like substance which is often seen to ooze out of the Newcastle coal when on the fire, and which makes it cake, is a good example. *Etym.*, *bitumen*, pitch.

Bituminous Shale. An argillaceous shale, much impregnated with bitumen, which is very common in the Coal Measures.

Blende. A metallic ore, a compound of the metal zink with sulphur. It is often found in brown shining crystals; hence its name among the German miners, from the word *blenden*, to dazzle.

Bluffs. High banks presenting a precipitous front to the sea or a river. A term used in the United States of North America.

Botryoidal. Resembling a bunch of grapes. *Etym.*, βοτρυς, *botrys*, a bunch of grapes, and ειδος, *eidos*, form.

Boulders. A provincial term for large rounded blocks of stone, lying on the surface of the ground, or sometimes imbedded in loose soil, different in composition from the rocks in their vicinity, and which have been therefore transported from a distance.

Breccia. A rock composed of angular fragments, connected together by lime or other mineral substance. An Italian term.

Calc Sinter. A German name for the deposits from springs holding carbonate of lime in solution—petrifying springs. *Etym.*, *kalk*, lime, *sintern*, to drop.

Calcaire Grossier. An extensive stratum, or rather series of strata, found in the Paris Basin, belonging to the Eocene tertiary period. *Etym.*, *calcaire*, limestone, and *grossier*, coarse.

Calcareous Rock. Limestone. *Etym*, *calx*, lime.

Calcareous Spar. Crystalized carbonate of lime.

Calcedony. A silicious simple mineral, uncrystalized. Agates are partly composed of calcedony.

Carbon. An undecomposed inflammable substance, one of the simple elementary bodies. Charcoal is almost entirely composed of it. *Etym.*, *carbo*, coal.

Carbonate of Lime. Lime combines with great avidity with carbonic acid, a gaseous acid, only obtained fluid when united with water; and all combinations of it with other substances are called *Carbonates*. All limestones are carbonates of lime, and quick-lime is obtained by driving off the carbonic acid, by heat.

Carbonated Springs. Springs of water, containing carbonic acid gas. They are very common, especially in volcanic countries; and sometimes contain so much gas, that if a little sugar be thrown into the water it effervesces like soda-water.

Carbonic Acid Gas. A natural gas, which often issues from the ground, especially in volcanic countries. *Etym.*, *carbo*, coal; because the gas is obtained by the slow burning of charcoal.

Carboniferous. A term usually applied, in a technical sense, to an ancient group of secondary strata; but any bed containing coal may be said to be carboniferous. *Etym.*, *carbo*, coal, and *fero*, to bear.

Cataclysm. A deluge. *Etym.*, κατακλυζω, *catacluzo*, to deluge.

Cephalopoda. A class of molluscous animals, having their organs of motion arranged round their head. *Etym.*, κεφαλη, *cephale*, head, and ποδα, *poda*, feet.

Cetacea. An order of vertebrated mammiferous animals, inhabiting the sea. The whale, dolphin, and narwal are examples. *Etym.*, *cete*, whale.

Chalk. A white earthy limestone, the uppermost of the secondary series of strata.

Chert. A silicious mineral, nearly allied to calcedony and flint, but less homogeneous and simple in texture. A gradual passage from chert to limestone is not uncommon.

Chloritic Sand. Sand colored green by an admixture of the simple mineral chlorite. *Etym.*, χλωρος, *chloros*, green.

Cleavage. Certain rocks, usually called Slate-rocks, may be cleaved into an indefinite number of thin laminæ, which are parallel to each other, but which are generally not parallel to the planes of the true strata or layers of deposition. The planes of cleavage, therefore, are distinguishable from those of stratification.

Clinkstone, called also phonolite, a feldspathic rock of the trap-family, usually fissile. It is sonorous when struck with a hammer, whence its name.

Coal Formation. This term is generally understood to mean the same as the Coal Measures, or Carboniferous group.

Coleoptera. An order of insects (Beetles) which have four wings, the upper pair being crustaceous, and forming a shield. *Etym.*, κολεος, *coleos*, a sheath, and πτερον, *pteron*, a wing.

Conformable. When the planes of one set of strata are generally parallel to those of another set, which are in contact, they are said to be conformable. *See Lign.* 79.

Congeners. Species which belong to the same genus.

Conglomerate, or **Pudding-stone.** Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be of a silicious, calcareous, or argillaceous nature. *Etym.*, *con*, together, *glomero*, to heap.

Conifera. An order of plants, which, like the fir and pine, bear cones or tops, in which the seeds are contained. *Etym.*, *conus*, cone, and *fero*, to bear.

Cosmogony, Cosmology. Words synonymous in meaning, applied to speculations respecting the first origin or mode of creation of the earth. *Etym.*, κοσμος, *kosmos*, the world, and γονη, *gonee*, generation, or λογος, *logos*, discourse.

Crag. A provincial name in Norfolk and Suffolk for certain tertiary deposits, usually composed of sand with shells, belonging to the Older Pliocene period.

Crater. The circular cavity at the summit of a volcano, from which the volcanic matter is ejected. *Etym.*, *crater*, a great cup or bowl.

Cretaceous. Belonging to chalk. *Etym.*, *creta*, chalk.

Crop Out. A miner's, or mineral surveyor's term, to express the rising up, or exposure at the surface, of a stratum or series of strata. *Lign.* 76.

Crust of the Earth. *See* "Earth's crust."

Crustacea. Animals having a shelly coating or crust, which they cast periodically. Crabs, shrimps, and lobsters, are examples.

Cryptogamic. A name applied to a class of plants, such as ferns, mosses, sea-weeds, and fungi, in which the fructification or organs of reproduction are concealed. *Etym.*, κρυπτος, *kryptos*, concealed, and γαμος, *gamos*, marriage

Crystals. Simple minerals are frequently found in regular forms, with facets like the drops of cut-glass of chandeliers. Quartz being often met with in rocks in such forms, and beautifully transparent, like ice, was called *rock-crystals*, κρυσταλλος, *crystallos*, being Greek for ice. Hence, the regular *forms* of other minerals are called crystals, whether they be clear or opake.

Crystalized. A mineral, which is found in regular forms, or crystals, is said to be crystalized.

Crystaline. The internal texture which regular crystals exhibit when broken, or a confused assemblage of ill-defined crystals. Loaf-sugar and statuary-marble have a *crystaline* texture. Sugar-candy and calcareous spar are crystalized.

Cupriferous. Copper-bearing. *Etym. cuprum*, copper, and *fero*, to bear.

Cycadeæ. An order of plants, which are natives of warm climates, mostly tropical, although some are found at the Cape of Good Hope. They have a short stem, surmounted by a peculiar foliage, termed pinnated fronds, by botanists, which spreads in a circle. The term is derived from κυκας, *cycas*, a name applied by the ancient Greek naturalist, Theophrastus, to a palm.

Cyperaceæ. A tribe of plants, answering to the English sedges; they are distinguished from grasses by their stems being solid, and generally triangular, instead of being hollow and round. Together with *gramineæ*, they constitute what writers on botanical geography often call *glumaceæ*.

Debacle. A great rush of waters, which, breaking down all opposing barriers, carries forward the broken fragments of rocks, and spreads them in its course. *Etym.*, *débacler*, French, to unbar, to break up, as a river does at the cessation of a long-continued frost.

Delta. When a great river, before it enters the sea, divides into separate streams, they often diverge, and form two sides of a triangle, the sea being the base. The land included by the three lines, and which is invariably alluvial, was first called, in the case of the Nile, a delta, from its resemblance to the letter of the Greek alphabet which goes by that name, Δ. Geologists apply the term to alluvial land formed by a river at its mouth, without reference to its precise shape.

Denudation. The carrying away by the action of running water of a portion of the solid materials of the land, by which inferior rocks are laid bare. *Etym.*, *denudo*, to lay bare.

Deoxydized, Deoxydated. Deprived of oxygen. Disunited from Oxygen.

Desiccation. The act of drying up. *Etym.*, *desicco*, to dry up.

Detritus. Matter worn or rubbed off from rocks. *Etmy.*, *de*, from, and *tero*, to rub.

Dicotyledonous. A grand division of the vegetable kingdom, founded on the plant having two *cotyledons*, or seed-lobes. *Etym.*, δις, *dis*, double, κοτυληδον, cotyleden.

Dikes. When masses of the unstratified or igneous rocks—such as granite, trap, and lava—appear as if injected into rents in the stratified rocks, cutting across the strata, they form dikes. They are sometimes seen running along the ground, and projecting, like a wall, from the softer strata on both sides of them having wasted away; whence they were first called, in the north of England and in Scotland, *dikes*—a provincial name for wall. It is not easy to draw the line between dikes and veins. The former are generally of larger dimensions, and have their sides parallel for considerable distances; while veins have generally many ramifications, and these often thin away into slender threads. *Lign.* 80.

Diluvium. Those accumulations of gravel and loose materials, which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth. *Etym.*, *diluvium*, deluge.

Dip. When a stratum does not lie horizontally, but is inclined, it is said to *dip* towards some point of the compass, and the angle it makes with the horizon is called the angle of dip or inclination. *Lign.* 76.

Diptera. An order of insects, comprising those which have only two wings. *Etym.*, δις, *dis*, doub'e, and πτερον, *pteron*, wing.

Dolerite. One of the varieties of the Trap-rocks, composed of augite and feldspar.

Dolomite. A crystaline limestone, containing magnesia as a constituent part. Named after the French geologist, Dolomieu.

Dunes. Low hills of blown sand that skirt the shores of Holland, England, Spain, and other countries.

Earth's Crust. Such superficial parts of our planet as are accessible to human observation.

Ecpyrosis. A Greek term for a destruction by fire.

Elytra. The wing-sheaths, or upper crustaceous membranes, which form the superior wings in the tribe of beetles. They cover the body, and protect the true membraneous wing. *Etym.*, ελυτρον, *elytron*, a sheath.

Entomostraca. Cuvier's second section of Crustacea; so called from their relationship to insects. *Etym.*, εντομα, *entoma*, insects.

Eocene. A name given to the lowest division of the tertiary strata, containing an extremely small per-centage of living species among its fossil shells, which indicate the first commencement or dawn of the existing state of the animate creation. *Etym.*, ηως, *eos*, aurora, or the dawn, and καινος, *kainos*, recent.

Escarpment. The abrupt face of a ridge of high land. *Etym.*, *escarper*, French, to cut steep.

Estuaries. Inlets of the land, which are entered both by rivers and the tides of the sea. Thus we have the estuaries of the Thames, Severn, Tay, &c. *Etym.*, *æstus*, the tide.

Experimentum Crucis. A decisive experiment, so called, because, like a cross or direction-post, it directs men to true knowledge; or, as some explain it, because it is a kind of torture, whereby the nature of the thing is extorted, as it were, by violence.

Exuviæ. Properly speaking, the transient parts of certain animals, which they put off or lay down to assume new ones, as serpents and caterpillars shift their skins; but in geology it refers not only to the cast-off coverings of animals, but to fossil shells, and other remains which animals have left in the strata of the earth. *Etym.*, *exuere*, to put off or divest.

Faluns. A French provincial name for some tertiary strata, abounding in shells, in Touraine, which resemble in lithological characters the "Crag" of Norfolk and Suffolk.

Fault, in the language of miners, is the sudden interruption of the continuity of strata in the same plane, accompanied by a crack or fissure, varying in width from a mere line to several feet, which is generally filled with broken stone, clay, &c. *Lign.* 80.

Fauna. The various kinds of animals peculiar to a country, constitute its **Fauna**, as the various kinds of plants constitute its **Flora**. The term is derived from the **Fauni**, or rural deities, in Roman mythology.

Feldspar. A simple mineral, which, next to quartz, constitutes the chief material of rocks. The white angular portions in granite are feldspar. This mineral always contains some alkali in its composition. In *common feldspar* the alkali is potash; in another variety, called Albite or Cleavlandite, it is soda. Glassy feldspar is a term applied when the crystals have a considerable degree of transparency. *Compact* feldspar is a name of more vague signification. The substance so called, appears to contain both potash and soda.

Feldspathic. Of, or belonging to feldspar.

Ferruginous. Any thing containing iron. *Etym.*, *ferrum*, iron.

Floetz Rocks. A German term, applied to the secondary strata by the geologists of that country, because these rocks were supposed to occur most frequently in flat horizontal beds. *Etym.*, *flötz*, a layer of stratum.

Flora. The various kinds of trees and plants found in any country, constitute the **Flora** of that country, in the language of botanists.

Fluviatile. Belonging to a river. *Etym.*, *fluvius*, a river.

Foraminifera. A name given by D'Orbigny to a family of microscopic shells. Their different chambers are united by a small perforation or *foramen*. Recent observation has shown that some at least are not cephalopoda, as D'Orbigny supposed.

Formation. A group, whether of alluvial deposits, sedimentary strata, or igneous rocks, referred to a common origin or period.

Fossil. All minerals were once called fossils, but geologists now use the word only to express the remains of animals and plants found buried in the earth. *Etym.*, *fossilis*, any thing that may be dug out of the earth.

Fossiliferous. Containing organic remains.

Galena. A metallic ore, a compound of lead and sulphur. It has often the appearance of highly-polished lead. *Etym.*, γαλεω, *galeo*, to shine.

Garnet. A simple mineral, generally of a deep red color, crystalized; most commonly met with in mica-slate, but also in granite and other igneous rocks.

Gasteropoda. A division of the Testacea, in which, as in the limpet, the foot is attached to the body. *Etym.*, γαστηρ, *gaster*, belly, ποδα, *poda*, feet.

Gault. A provincial name, in the east of England, for a series of beds of clay and marl, the geological position of which is between the Upper and Lower Green-sand

Gavial. A kind of crocodile, found in India.

Gem, or **Gemmule**, from the Latin *gemma*, a bud. The term. applied to zoophytes, means a young animal not confined within an envelop or egg.

Geology, Geognosy. Both mean the same thing; but with an unnecessary degree of refinement in terms, it has been proposed to call our description of the structure of the earth, *geognosy*. (*Etym.*, γεα, *gea*, and γινωσκω, *ginosco*, to know,) and our theoretical speculations, as to its formation, *geology*, (*Etym.*, γεα, and λογος, *logos*, a discourse.)

Glacier. Vast accumulations of ice and hardened snow in the Alps and other lofty mountains. *Etym.*, *glace*, French for ice.

Glacis. A term borrowed from the language of fortification, where it means an easy insensible slope or declivity, less steep than a *talus*, which see.

Gneiss. A stratified primary rock, composed of the same materials as granite, but having usually a larger proportion of mica and a laminated texture. The word is a German miner's term.

Gramineæ. The order of plants to which grasses belong. *Etym.*, *gramen*, grass.

Granite. An unstratified or igneous rock, generally found inferior to, or associated with the oldest of the stratified rocks, and sometimes penetrating them in the form of dikes and veins. It is usually composed of three simple minerals, feldspar, quartz, and mica, and derives its name from having a coarse *granular* structure; *granum*, Latin for grain. Westminster, Waterloo, and London bridges, and the paving-stones in the carriage-way of the London streets, afford good examples of the most common varieties of granite.

Graywacke. *Grauwacke*. a German name, generally adopted by geologists for some of the most ancient fossiliferous strata. The rock is very often of a gray color; hence the name, *grau*, being German for gray, and *wacke* being a provincial miner's term.

Greensand. Beds of sand, sandstone, limestone, belonging to the Cretaceous Period. The name is given to these beds, because they often, but not always, contain an abundance of green earth, or chlorite, scattered through the substance of the sandstone, limestone, &c.

Greenstone. A variety of trap, composed of hornblend and feldspar.

Grit. A provincial name for a coarse-grained sand-stone.

Gypsum. A mineral, composed of lime and sulphuric acid, hence called, also, *sulphate* of *lime*. Plaster and stucco are obtained by exposing gypsum to a strong heat. It is found so abundantly near Paris, that plaster of Paris is a common term in this country for the white powder of which casts are made. The term is used by Pliny for a stone used for the same purposes by the ancients. The derivation is unknown.

Gypseous, of or belonging to gypsum.

Gyrogonites. Bodies found in fresh-water deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of fresh-water plants of the genus *Chara*. *Etym.*, γυρος, *gyros*, curved, and γονος, *gonos*, seed, on account of their external structure.

Hemiptera. An order of insects, so called from a peculiarity in their wings, the superior being coriaceous at the base, and membraneous at the apex, ἡμισυ, *hemisu*, half, and πτερον, *pteron*, wing.

Hornblend. A simple mineral, of a dark green or black color, which enters largely into the composition of several varieties of the Trap-rocks.

Hornstone. A silicious mineral substance, sometimes approaching nearly to flint, or common quartz. It has a conchoidal fracture, and is infusible, which distinguishes it from compact feldspar.

Humerus. The bone of the upper arm.

Hydrophytes. Plants which grow in water. *Etym.*, ὑδωρ, *hydor*, water, and φυτον, *phyton*, plant.

Hypogene Rocks. Those rocks which are *nether-formed*, or which have not assumed their present form and structure at the surface, such as granite, gneiss, &c. This term, which includes both the plutonic and metamorphic rocks, is substituted for *primary*, because some members of both these classes, such as granite and gneiss, are posterior to many secondary or fossiliferous rocks. *Etym.*, ὑπο, *hypo*, under and γινομαι, *ginomai*, to be formed or produced.

Iceberg. Great masses of ice, often the size of hills, which float in the polar and adjacent seas. *Etym.*, ice, and berg, German for hill.

Ichthyosaurus. A gigantic fossil marine reptile, intermediate between a crocodile and a fish. *Etym.*, ιχθυς, *icthus*, a fish, and σαυρα, *saura*, a lizard.

Igneous Rocks. All rocks, such as lava, trap, and granite, known or supposed to have been melted by volcanic heat.

Incandescent. White hot. Having a more intense degree of heat than red heat.

Induction. A consequence, inference, or general principle, drawn from a number of particular facts or phenomena The inductive philosophy, says Mr. Whewell, has been rightly described as a science which ascends from particular facts to general principles, and then descends again from these general principles to particular applications.

Infusory Animalcules. Minute living creatures, found in many *infusions;* and the term *infusoria* has been given to all such animalcules, whether found in infusions or in stagnant water, vinegar, &c.

Inspissated. Thickened. *Etym.*, *spissus*, thick.

Invertebrated Animals. Animals which are not furnished with a back-bone. For a further explanation, *see* "Vertebrated Animals."

Isothermal. Such zones or divisions of the land, ocean, or atmosphere, which have an equal degree of mean annual warmth, are said to be isothermal, from ισος *isos*, equal, and θερμη, *therme*, heat.

Joints. Fissures or lines of parting in rocks, often at right angles to the planes of stratification. The partings which divide columnar basalt into prisms, are joints.

Jura Limestone. The limestones belonging to the Oolitic Group, constitute the chief part of the mountains of the Jura, between France and Switzerland; and hence the geologists of the Continent have given the name to the group.

Keuper, a German name for a member of the Upper New Red Sandstone.

Kimmeridge Clay. A thick bed of clay, constituting a member of the Oolite Group. So called, because it is found well developed at Kimmeridge, in the isle of Purbeck, Dorsetshire.

Lacustrine. Belonging to a lake. *Etym.*, *lacus*, a lake.

Lamantine. A living species of the herbivorous Cetacea, or whale tribe, which inhabits the mouths of rivers on the coast of Africa and South America: the sea-cow.

Lamelliferous. Having a structure consisting of thin plates or leaves like paper. *Etym.*, *lamella*, the diminutive of *lamina*, plate, and *fero*, to bear.

Laminæ. Latin for plates; used in geology for the smaller layers of which a stratum is frequently composed.

Landslip. A portion of land that has slid down in consequence of disturbance by earthquake, or from being undermined by water washing away the lower beds which supported it.

Lapidification—Lapidifying process. Conversion into stone. *Etym.*, *lapis*, stone, and *fio*, to make.

Lapilli. Small volcanic cinders. *Lapillus*, a little stone.

Lava. The stone which flows in a melted state from a volcano.

Lepidodendron, a genus of fossil plants of the Coal Measures, intermediate in character between the Lycopodiums and coniferous plants.

Leucite. A simple mineral, found in volcanic rocks, crystalized, and of a white color. *Etym.*, λευκος, *leucos*, white.

Lias. A provincial name for an argillaceous limestone, characterized, together with its associated beds, by peculiar fossils, and forming a particular group of strata, interposed between the Oolite and New Red Sandstone.

Ligniperdous. A term applied to insects which destroy wood. *Etym.*, *lignum*, wood, and *perdo*, to destroy.

Lignite. Wood converted into a kind of coal. *Etym.*, *lignum*, wood.

Lithodomi. Molluscous animals, which form holes in solid rocks, in which they lodge themselves. The holes are not perforated mechanically, but the rock appears to be dissolved. *Etym.*, λιθος, *lithos*, stone, and δεμω, *demo*, to build.

Lithogenous Polyps. Animals which form coral.

Lithographic Stone. A slaty compact limestone, of a yellowish color and fine grain, used in lithography, which is the art of drawing upon and printing from stone. *Etym.*, λιθος, *lithos*, stone, and γραφω, *grapho*, to write.

Lithoidal. Having a stony structure.

Lithological. A term expressing the stony structure or character of a mineral mass. We speak of the lithological character of a stratum as distinguished from its zoological character. *Etym.*, λιθος, *lithos*, stone, and λογος, *logos*, discourse.

LITHOPHAGI. Molluscous animals, which form holes in solid stones. *See* "Lithodomi." *Etym.*, $\lambda\iota\theta o\varsigma$, *lithos*, stone, and $\phi\alpha\gamma\omega$, *phago*, to eat.
LITHOPHYTES. The animals which form Stone-coral.
LITTORAL. Belonging to the shore. *Etym.*, *littus*, the shore.
LOAM. A mixture of sand and clay.
LOPHIODON. A genus of extinct quadrupeds, allied to the tapir, named from eminences on the teeth.
LYCOPODIACEÆ. Plants of an inferior degree of organization to Coniferæ, some of which they very much resemble in foliage, but all recent species are infinitely smaller. Many of the fossil species are as gigantic as recent Coniferæ. Their mode of reproduction is analogous to that of ferns. In English they are called club-mosses; generally found in mountainous heaths in the north of England
LYDIAN STONE. Flinty slate; a kind of quartz or flint, allied to Hornstone, but of a grayish-black color.

MACIGNO. In Italy this term has been applied to a silicious sandstone, sometimes containing calcareous grains, mica, &c.
MADREPORE. A genus of corals, but generally applied to all the corals distinguished by superficial star-shaped cavities. There are several fossil species.
MAGNESIAN LIMESTONE. An extensive series of beds, the geological position of which is immediately above the Coal Measures; so called, because the limestone, the principal member of the series, contains much of the earth magnesia as a constituent part.
MAMMIFEROUS. Mammifers. Animals which give suck to their young. To this class all the warm-blooded quadrupeds, and the Cetacea, or whales, belong. *Etym.*, *mamma*, a breast, *fero*, to bear.
MAMMILLARY. A surface which is studded over with rounded projections. *Etym.*, *mammilla*, a little breast or pap.
MAMMOTH. An extinct species of the elephant, (*E. primigenius.*) of which the fossil bones are frequently met with in various countries. The name is of Tartar origin, and is used in Siberia for animals that burrow under ground.
MANATI. One of the Cetacea, the sea-cow, or lamantine
MARL. A mixture of clay and lime; usually soft, but sometimes hard, in which case it is called indurated marl.
MARSUPIAL ANIMALS. A tribe of quadrupeds having a sack or pouch under the belly, in which they carry their young, the kangaroo is a well-known example. *Etym.*, *marsupium*, a purse.
MASTODON. A genus of fossil extinct quadrupeds, allied to the elephants; so called from the form of the hind teeth or grinders, which have their surface covered with conical mamillary crests. *Etym.*, $\mu\alpha\sigma\tau o\varsigma$, *mastos*, pap, and $o\delta o\upsilon\varsigma$, *odous*, tooth.
MATRIX. If a simple mineral or shell, in place of being detached, be still fixed in a portion of rock, it is said to be in its matrix. *Matrix*, womb.
MECHANICAL ORIGIN, ROCKS OF. Rocks composed of sand, pebbles, or fragments, are so called, to distinguish them from those of a uniform crystaline texture, which are of chemical origin.
MEDUSÆ. A genus of marine radiated animals, without shells; so called, because their organs of motion spread out like the snaky hair of the fabulous Medusa.
MEGALOSAURUS. A fossil gigantic amphibious animal, of the saurian or lizard and crocodile tribe. *Etym.*, $\mu\epsilon\gamma\alpha\lambda\eta$, *megale*, great, and $\sigma\alpha\upsilon\rho\alpha$, *saura*, lizard.
MEGATHERIUM. A fossil extinct quadruped, resembling a gigantic sloth. *Etym.*, $\mu\epsilon\gamma\alpha$, *mega*, great, and $\theta\eta\rho\iota o\nu$, *therion*, a wild beast.
MELASTOMA. A genus of MELASTOMACEÆ, an order of exotic plants of the evergreen tree, and shrubby kinds. *Etym.*, $\mu\epsilon\lambda\alpha\varsigma$, *melas*, black, and $\sigma\tau o\mu\alpha$, *stoma*, mouth; because the fruit of one of the species stains the lips.
MESOTYPE. A simple mineral, white, and needle-shaped, one of the Zeolite family, frequently met with in the Trap-rocks.
METAMORPHIC ROCKS. A stratified division of hypogene rocks, highly crystaline, such as gneiss and mica-shist, and so named because they have been *altered* by plutonic action. *Etym.*, $\mu\epsilon\tau\alpha$, *meta*, trans, and $\mu o\rho\phi\eta$, *morphe*, form.
MICA. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. It is often called *talc* in common life; but mineralogists apply the term talc to a different mineral. The brilliant scales in granite are mica. *Etym.*, *mico*, to shine.
MICA-SLATE, MICA-SHIST, MICACEOUS SHISTUS. One of the metamorphic or crystaline stratified rocks, of the hypogene class, which is characterized by being composed of a large proportion of mica united with quartz.

Miocene. A division of tertiary strata intervening between the Eocene and Pliocene formations; so called, because a minority of its fossil shells are referable to living species *Etym.*, μειων, *meion*, less, and καινος, *kainos*, recent.

Molasse. A provincial name for a soft green sandstone, associated with marl and conglomerates, belonging to the Miocene Tertiary Period, extensively developed in the lower country of Switzerland. *Etym.*, French, *molle*, soft.

Mollusca, Molluscous Animals. Animals, such as shell-fish, which, being devoid of bones, have soft bodies. *Etym.*, *mollis*, soft.

Monad. The smallest of visible animalcules, spoken of by Buffon and his followers as constituting the elementary molecules of organic beings.

Monitor. An animal of the saurian or lizard tribe, species of which are found in both the fossil and recent state.

Monocotyledonous. A grand division of the vegetable kingdom, (including palms, grasses, Liliaceæ, &c.,) founded on the plant having only one *cotyledon*, or seed-lobe. *Etym.*, μονος, *monos*, single, κοτυληδον, *cotyledon*.

Moraine, a Swiss term for the débris of rocks brought into valleys by glaciers.

Moschus. A quadruped, resembling the chamois, or mountain goat, from which the perfume musk is obtained.

Mountain Limestone, or Carboniferous Limestone. A series of limestone strata, of marine origin, usually forming the lowest member of the Coal Measures.

Moya. A term applied in South America to mud poured out from volcanoes during eruptions.

Multilocular. Many-chambered; a term applied to those shells which, like the nautilus, ammonite, and others, are divided into many compartments. *Etym.*, *multus*, many, and *loculus*, a partition.

Muriate of Soda. The scientific name for common culinary salt, because it is composed of muriatic acid and the alkali soda.

Musaceæ. A family of tropical monocotyledonous plants, including the banana and plantains.

Muschelkalk. A limestone, belonging to the Upper New Red Sandstone group. Its position is between the Magnesian Limestone and the Lias. This formation has not yet been found in England, and the German name is adopted by English geologists. The word means shell-limestone. *Etym.*, *muschel*, shell, and *kalkstein*, limestone.

Naphtha. A very thin, volatile, inflammable, and fluid mineral substance, of which there are springs in many countries, particularly in volcanic districts.

New Red Sandstone. A formation so named, because it consists chiefly of sandy and argillaceous strata, the predominant color of which is brick-red, but containing portions which are of a greenish-gray. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. This formation is divided into the Upper New Red, in which the Muschelkalk is included, and the Lower New Red, of which the Magnesian Limestone is a member.

Nodule. A rounded irregular-shaped lump or mass. *Etym.*, diminutive of *nodus*, knot.

Normal Groups. Groups of certain rocks, taken as a rule or standard. *Etym.*, *norma*, rule or pattern

Nucleus. A solid central piece, around which other matter is collected. The word is Latin for kernel.

Nummulites. An extinct genus of the order of molluscous animals, called Cephalopoda, of a thin lenticular shape, internally divided into small chambers. *Etym.*, *nummus*, Latin for money, and λιθος, *lithos*, stone, from its resemblance to a coin.

Nuphar. A yellow water-lily.

Obsidian. A volcanic product, or species of lava, very like common green bottle-glass, which is almost black in large masses, but semi-transparent in thin fragments. Pumice-stone is obsidian in a frothy state; produced, most probably, by water that was contained in, or had access to the melted stone, and converted into steam. There are very often portions in masses of solid obsidian, which are partially converted into pumice.

Ochre. A yellow powder, a combination of some earth with oxyd of iron.

Ogygian Deluge. A great inundation mentioned in fabulous history, supposed to have taken place in the reign of Ogyges, in Attica, whose death is fixed, in Blair's Chronological Tables, in the year 1764 before Christ.

Old Red Sandstone. A formation immediately below the Carboniferous

Group. The term Devonian has been recently proposed for strata of this age, because in Devonshire they are largely developed, and contain many organic remains.

OLIVINE. An olive-colored, semi-transparent, simple mineral, very often occurring in the form of grains and of crystals in basalt and lava.

OOLITE, OOLITIC. A limestone; so named, because it is composed of rounded particles, like the roe or eggs of a fish. The name is also applied to a large group of strata, characterized by peculiar fossils, in which limestone of this texture occurs. *Etym.*, ωον, *oon*, egg, and λιθος, *lithos*, stone.

OPALIZED WOOD. Wood petrified by silicious earth, and acquiring a structure similar to the simple mineral called opal.

OPHIDIOUS REPTILES. Vertebrated animals, such as snakes and serpents, *Etym.*, οφις *ophis*, a serpent.

ORGANIC REMAINS. The remains of animals and plants (*organized* bodies) found in a fossil state.

ORTHOCERATA, or ORTHOCERÆ. An extinct genus of the order of molluscous animals, called Cephalopoda, that inhabited a long-chambered conical shell, like a straight horn. *Etym.*, ορθος, *orthos*, straight, and κερας, *ceras*, horn.

OSSEOUS BRECCIA. The cemented mass of fragments of bones of extinct animals, found in caverns and fissures. *Osseous* is a Latin adjective, signifying bony.

OSTEOLOGY. That division of anatomy which treats of the bones; from οστεον, *osteon*, a bone, and λογος, *logos*, a discourse.

OUTLIERS. When a portion of the stratum occurs at some distance, detached from the general mass of the formation to which it belongs, some practical mineral surveyors call it an *outlier*, and the term is adopted in geological language. *Lign.* 78.

OVATE. The shape of an egg. *Etym.*, *ovum*, egg.

OVIPOSITING. The laying of eggs.

OXYD. The combination of a metal with oxygen; rust is oxyd of iron.

OXYGEN. One of the constituent parts of the air of the atmosphere; that part which supports life. For a further explanation of the word, consult elementary works on chemistry.

PACHYDERMATA. An order of quadrupeds, including the elephant, rhinoceros, horse, pig, &c., distinguished by having thick skins. *Etym.*, παχυς, *pachus*, thick, and δερμα, *derma*, skin or hide.

PACHYDERMATOUS. Belonging to Pachydermata.

PALÆOTHERIUM, PALEOTHERE. A fossil extinct quadruped, belonging to the order Pachydermata, resembling a pig or tapir, but of great size. *Etym.*, παλαιος, *palaios*, ancient, and θηριον, *therion*, wild beast.

PALÆONTOLOGY. The science which treats of fossil remains, both animal and vegetable. *Etym.*, παλαιος, *palaios*, ancient, οντα, *onta*, beings, and λογος, *logos*, a discourse.

PELAGIAN, PELAGIC. Belonging to the *deep* sea. *Etym.*, *pelagus*, sea.

PEPERINO. An Italian name for a particular kind of volcanic rock, formed, like tuff, by the cementing together of volcanic sand, cinders, or scoriæ, &c.

PETROLEUM. A liquid mineral pitch, so called because it is seen to ooze like oil out of the rock. *Etym.*, *petra*, rock, and *oleum*, oil.

PHÆNOGAMOUS, or PHANEROGAMIC PLANTS. A name given by Linnæus to those plants in which the reproductive organs are apparent. *Etym.*, φανερος, *phaneros*, evident, or φαινω, *phaino*, to show, and γαμος, *gamos*, marriage.

PHLEGRÆAN FIELDS. Campi Phlegræi, or "the Burnt Fields." The country around Naples, so named by the Greeks, from the traces of igneous action every where visible.

PHONOLITE. *See* "Clinkstone."

PHRYGANEA. A genus of four-winged insects, the larvæ of which, called caddis-worms, are used by anglers as a bait.

PHYSICS. The department of science which treats of the properties of natural bodies, laws of motion, &c.; sometimes called natural philosophy and mechanical philosophy. *Etym.*, φυσις, *physis*, nature.

PHYTOLOGY, PHYTOLOGICAL. The department of science which relates to plants—synonymous with botany and botanical. *Etym.*, φυτον, *phyton*, plant, and λογος, *logos*, discourse.

PHYTOPHAGOUS. Plant-eating. *Etym.*, φυτον, *phyton*, plant, and φαγω, *phago*, to eat

PISOLITE. A stone, possessing a structure like an agglutination of pease. *Etym.*, πισον, *pison*, pea, and λιθος, *lithos*, stone.

PISTIA. The plant mentioned by Malte-Brun is probably the *Pistia Stratiotes*, a floating plant, related to English duck-weed, but very much larger.

Pit Coal. Ordinary coal; called so, because it is obtained by sinking pits in the ground.

Pitch-stone. A rock of uniform texture, belonging to the unstratified and volcanic classes, which has an unctuous appearance, like indurated pitch.

Plastic Clay. One of the beds of the Eocene Tertiary Period; so called, because it is used for making pottery. The formation to which this name is applied, is a series of beds, chiefly sands, with which the clay is associated. *Etym.*, πλασσω, *plasso*, to form or fashion.

Plesiosaurus. A fossil extinct amphibious animal, resembling the saurian, or lizard and crocodile tribe. *Etym.*, πλησιον, *plesion*, near to, and σαυρα, *saura*, a lizard.

Pliocene, Older and Newer. Two divisions of the tertiary period which are the most modern, and of which the largest part of the fossil shells are of recent species. *Etym.*, πλειων, *pleion*, more, and καινος, *kainos*, recent.

Plutonic Action. The influence of volcanic heat and other subterranean causes under pressure.

Plutonic Rocks. Granite, porphyry, and other igneous rocks, supposed to have consolidated from a melted state at a great depth from the surface.

Polyparia. Corals. A numerous class of invertebrated animals, belonging to the great division called Radiata.

Porphyry. An unstratified or igneous rock. The term is as old as the time of Pliny, and was applied to a red rock with small, angular, white bodies diffused through it, which are crystalized feldspar, brought from Egypt. The term is hence applied to every species of unstratified rock in which detached crystals of feldspar or some other minerals are diffused through a base of other mineral composition. *Etym.*, πορφυρα, *porphyra*, purple.

Portland Limestone, Portland Beds. A series of limestone strata, belonging to the upper part of the Oolite Group, found chiefly in England, in the island of Portland, on the coast of Dorsetshire. The great supply of the building-stone used in London, is from these quarries.

Puzzuolana. Volcanic ashes, largely used as mortar for buildings, similar in nature to what is called, in this country, Roman cement. It gets its name from Puzzuoli, a town in the bay of Naples, from which it is shipped in large quantities to all parts of the Mediterranean.

Precipitate. Substances which, having been dissolved in a fluid, are separated from it by combining chemically, and forming a solid, which falls to the bottom of the fluid. This process is the opposite to that of chemical solution.

Producta. An extinct genus of fossil bivalve shells, occurring only in the older secondary rocks. It is closely allied to the living genus Terebratula.

Pterodactyle. A flying reptile: species of this genus have been found in the Oolite and Muschelkalk. Some of the finger-joints are lengthened, so as to serve as the expansors of a membraneous wing. Hence the name *wing-fingered*. *Etym.*, πτερον *pteron*, a wing, and δακτυλος, *dactylos*, a finger.

Pubescence. The soft hairy down on insects. *Etym.*, *pubesco*, the first growth of the beard.

Pudding-stone. *See* "Conglomerate."

Pumice. A light spongy lava, chiefly feldspathic, of a white color, produced by gasses, or watery vapor getting access to the particular kind of glassy lava, called obsidian, when in a state of fusion: it may be called the froth of melted volcanic glass. The word comes from the Latin name of the stone, *pumex*.

Purbeck Limestone, Purbeck Beds. Limestone strata, belonging to the Wealden Group, which intervenes between the Green-sand and the Oolite.

Pyrites. (Iron.) A compound of sulphur and iron, found usually in yellow shining crystals like brass, and in almost every rock, stratified and unstratified. The shining metallic bodies so often seen in common roofing-slate, are a familiar example of the mineral. The word is Greek, and comes from πυρ, *pyr*, fire; because, under particular circumstances, the stone produces spontaneous heat, and even inflammation.

Pyrometer. An instrument for measuring intense degrees of heat.

Quadrumana. The order of mammiferous animals to which apes belong. *Etym.*, *quadrus*, a derivative of the Latin word for the number four, and, *manus*, hand, the four feet of those animals being, in some degree, usable as hands.

Qua-qua-versal Dip. The dip of beds to all points of the compass around a centre, as in the case of beds of lava round the crater of a volcano. *Etym.* *quâ-quâ versum*, on every side.

QUARTZ. A German provincial term, universally adopted in scientific language for a simple mineral, composed of pure silex, or earth of flints: rock-crystal is an example.
QUARTZITE, or QUARTZ ROCK. An aggregate of grains of quartz, sometimes passing into compact quartz.
RED MARL. A term often applied to the New Red Sandstone.
RETICULATE. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.
ROCK SALT. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire; and it is then called *rock-salt*.
RUBBLE. A term applied by quarry-men to the upper fragmentary and decomposed portion of a mass of stone.
RUMINANTIA. Animals which ruminate or chew the cud, such as the ox, deer, &c. *Etym.*, the Latin verb *rumino*, meaning the same thing.
SACCHAROID, SACCHARINE. When a stone has a texture resembling that of loaf-sugar. *Etym.* σακχαρ, *sacchar*, sugar, and ειδος, *eidos*, form.
SALT SPRINGS. Springs of water containing a large quantity of common salt. They are very abundant in Cheshire and Worcestershire, and culinary salt is obtained from them by mere evaporation.
SANDSTONE. Any stone which is composed of an agglutination of grains of sand, whether calcareous, silicious, or of any other mineral nature.
SAURIAN. Any animal belonging to the lizard tribe. *Etym.*, σαυρα, *saura*, a lizard.
SHIST is often used as synonymous with slate; but it may be very useful to distinguish between a shistose and a slaty structure. The hypogene or primary *shist*, as they are termed, such as gneiss, mica-shist, and others, cannot be split into an indefinite number of parallel laminæ, like rocks which have a true slaty cleavage. The uneven shistose layers of mica-shist and gneiss, are probably layers of deposition, which have assumed a crystaline texture. *See* "Cleavage." *Etym.*, *schistus*, adj. Latin, that which may be split.
SHISTOSE ROCKS. *See* "Shist."
SCORIÆ. Volcanic cinders. The word is Latin for cinders.
SEAMS. Thin layers, which separate two strata of greater magnitude.
SECONDARY STRATA. An extensive series of the stratified rocks which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them, called *primary*, and from a third series above them, called *tertiary*.
SECULAR REFRIGERATION. The periodical cooling and consolidation of the globe from a supposed original state of fluidity from heat. *Sæculum*, age or period.
SEDIMENTARY ROCKS are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.
SELENITE. Crystalized gypsum, or sulphate of lime—a simple mineral.
SEPTARIA. Flattened balls of stone, generally a kind of iron-stone, which, on being split, are seen to be separated in their interior into irregular masses. *Etym.*, *septa*, inclosures.
SERPENTINE. A rock usually containing much magnesian earth, for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock. Its name is derived from frequently presenting contrasts of color, like the skin of some serpents.
SHALE. A provincial term, adopted by geologists, to express an indurated slaty clay. *Etym.*, German, *scalen*, to peel, to split.
SHELL MARL. A deposit of clay, peat, and other substances, mixed with shells, which collects at the bottom of lakes.
SHINGLE. The loose and completely water-worn gravel on the sea-shore.
SILEX. The name of one of the pure earths, being the Latin word for *flint* which is wholly composed of that earth. French geologists have applied it as a generic name for all minerals composed entirely of that earth, of which there are many of different external forms.
SILICA. One of the pure earths. *Etym*, *silex*, flint, because found in that mineral.
SILICATE. A chemical compound of silica and another substance, such as silicate of iron. Consult elementary works on chemistry.
SILICIOUS. Of, or belonging to the earth of flint. *Etym.*, *silex*, which see. A silicious rock is one mainly composed of silex.
SILICIFIED. Any substance that is petrified or mineralized by *silicious* earth.
SILT. The more comminuted sand, clay, and earth, which is transported by running water. It is often accumulated by currents in banks. Thus, the mouth of a river is silted up when its entrance into the sea is impeded by such accumulation of loose materials.

Simple Mineral. Individual mineral substances, as distinguished from rocks, which last are usually an aggregation of simple minerals. They are not simple in regard to their nature; for, when subjected to chemical analysis, they are found to consist of a variety of different substances. Pyrites is a simple mineral, in the sense we use the term, but it is a chemical compound of sulphur and iron.

Sinter, Calcareous or Silicious. A German name for a rock precipitated from mineral waters. *Etym.*, *sintern*, to drop.

Slate. *See* "Cleavage" and "Shist."

Solfatara. A volcanic vent, from which sulphur, sulphureous, watery, and acid vapours and gasses are emitted.

Sporules. The reproductory corpuscula (minute bodies) of cryptogamic plants. *Etym.*, *σπορα*, *spora*, a seed.

Stalactite. When water holding lime in solution deposits it as it drops from the roof of a cavern, long rods of stone hang down like icicles, and these are called *stalactites*. *Etym.*, *σταλαζω*, *stalazo*, to drop.

Stalagmite. When water holding lime in solution drops on the floor of a cavern, the water evaporating leaves a crust composed of layers of limestone: such a crust is called *stalagmite* from *σταλαγμα*, *stalagma*, a drop, in opposition to *stalactite*, which see.

Statical Figure. The figure which results from the equilibrium of forces. From *στατος*, *statos*, stable, or standing still.

Sternum. The breast-bone, or the flat bone occupying the front of the chest.

Stilbite. A crystalized simple mineral, usually white, one of the Zeolite family, frequently included in the mass of the Trap-rocks.

Stratified. Rocks arranged in the form of *strata*, which see.

Stratification. An arrangement of rocks in *strata*, which see.

Strata, Stratum. The term stratum, derived from the Latin verb *struo*, to strew or lay out, means a bed or mass of matter spread out over a certain surface by the action of water, or in some cases by wind. The deposition of successive layers of sand and gravel in the bed of a river, or in a canal, affords a perfect illustration both of the form and origin of stratification. A large portion of the masses constituting the earth's crust are thus stratified, the successive strata of a given rock preserving a general parallelism to each other; but the planes of stratification not being perfectly parallel, throughout a great extent, like the planes of *cleavage*, which see.

Strike. The direction or line of bearing of strata, which is always at right angles to their prevailing dip.

Stufas. Jets of steam issuing from fissures in volcanic regions, at a temperature often above the boiling point.

Subapennines. Low hills, which skirt or lie at the foot of the great chain of the Apennines in Italy. The term Subapennine is applied geologically to a series of strata of the Older Pliocene Period.

Syenite. A kind of granite; so called, because it was brought from Syene in Egypt.

Talus. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap, called a talus. The term is borrowed from the language of fortification, where *talus* means the outside of a wall, of which the thickness is diminished by degrees, as it rises in height, to make it the firmer.

Tarsi. The feet in insects, which are articulated, and formed of five or a less number of joints.

Tertiary Strata. A series of sedimentary rocks, with characters which distinguish them from two other great series of strata—the secondary and primary—which lie *beneath* them.

Testacea. Molluscous animals, having a shelly covering. *Etym.*, *testa*, a shell, such as snails, whelks, oysters, &c.

Thermal. Hot. *Etym.*, *θερμος*, *thermos*, hot.

Thermo-electricity. Electricity developed by heat.

Thin out. When a stratum, in the course of its prolongation in any direction, becomes gradually less in thickness, the two surfaces approach nearer and nearer; and when at last they meet, the stratum is said to thin out, or disappear.

Trachyte. A variety of lava, essentially composed of glassy feldspar, and frequently having detached crystals of feldspar in the base or body of the stone, giving it the structure of porphyry. It sometimes contains hornblend and augite; and when these last predominate, the trachyte passes into the varieties of trap called Greenstone, Basalt, Dolorite, &c. The term is derived from *τραχυς*, *trachus*, rough, because the rock has a peculiar rough feel.

Trap and **Trappean Rocks**. Volcanic rocks, composed of feldspar, augite, and hornblend. The various proportions and state of aggregation of these simple minerals, and differences in external forms, give rise to varieties, which have received distinct appellations, such as Basalt, Amygdaloid, Dolorite, Greenstone, and others. The term is derived from *trappa*, a Sweedish word for stair, because the rocks of this class sometimes occur in large tabular masses, rising one above another, like steps.

Travertin. A white concretionary limestone, usually hard and semi-crystaline, deposited from the water of springs holding lime in solution.—*Etym*. This stone was called by the ancient Lapis Tiburtinus, the stone being formed in great quantity by the river Anio, at Tibur, near Rome. Some suppose travertin to be an abbreviation of trasteverino, from transtiburtinus.

Tripoli. The name of a powder, used for polishing metals and stones, first imported from Tripoli, which, as well as a certain kind of silicious stone of the same name, has been lately found to be composed of the flinty cases of Infusoria.

Trophi, of Insects. Organs which form the mouth, consisting of an upper and under lip, and comprising the parts called mandibles, maxillæ, and palpi.

Tufa, Calcareous. A porous rock, deposited by calcareous waters on their exposure to the air, and usually containing portions of plants and other organic substances incrusted with carbonate of lime. The more solid form of the same deposit is called "travertin," into which it passes.

Tufa, Volcanic. *See* "Tuff."

Tufaceous. A rock, with the texture of tuff, or tufa, which see.

Tuff, or **Tufa, Volcanic**. An Italian name for a variety of volcanic rock, of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoriæ and loose materials ejected from a volcano.

Turbinated. Shells which have a spiral or screw-form structure. *Etym*., *turbinatus*, made like a top.

Turrilite. An extinct genus of chambered shells, allied to the Ammonites, having the siphuncle near the dorsal margin.

Unconformable. *See* "Conformable."

Unoxydized, Unoxydated. Not combined with oxygen.

Veins, Mineral. Cracks in rocks, filled up by substances different from the rock, which may either be earthy or metallic. Veins are sometimes many yards wide; and they ramify or branch off into innumerable smaller parts, often as slender as threads, like the veins in an animal: hence their name.

Vertebrated Animals. A great division of the animal kingdom, including all those which are furnished with a back-bone, as the Mammalia, birds, reptiles, and fishes. The separate joints of the back-bone are called *vertebræ*, from the Latin verb *verto*, to turn.

Vesicle. A small, circular, inclosed space, like a little bladder. *Etym*., diminutive of *vesica*, Latin for a bladder.

Vitrification. The conversion of a body into glass by heat.

Volcanic Bombs. Volcanoes throw out sometimes detached masses of melted lava, which, as they fall, assume rounded forms, (like bomb-shells,) and are often elongated into a pear-shape.

Volcanic Foci. The subterranean centres of action in volcanoes, where the heat is supposed to be in the highest degree of energy.

Wacke. A rock nearly allied to basalt, of which it may be regarded as a soft and earthy variety.

Warp. The deposit of muddy waters, artificially introduced into low lands.

Zeolite. A family of simple minerals, including stilbite, mesotype, analcime, and some others, usually found in the trap or volcanic rocks. Some of the most common varieties swell or boil up when exposed to the blow-pipe, and hence the name of ζεω, *zeo*, to boil, and λιθος, *lithos*, stone.

Zoophytes. Corals, sponges, and other aquatic animals allied to them; so called because, while they are the habitation of animals, they are fixed to the ground, and have the forms of plants. *Etym*., ζωον, *zoon*, animal, and φυτον, *phyton*, plant.

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